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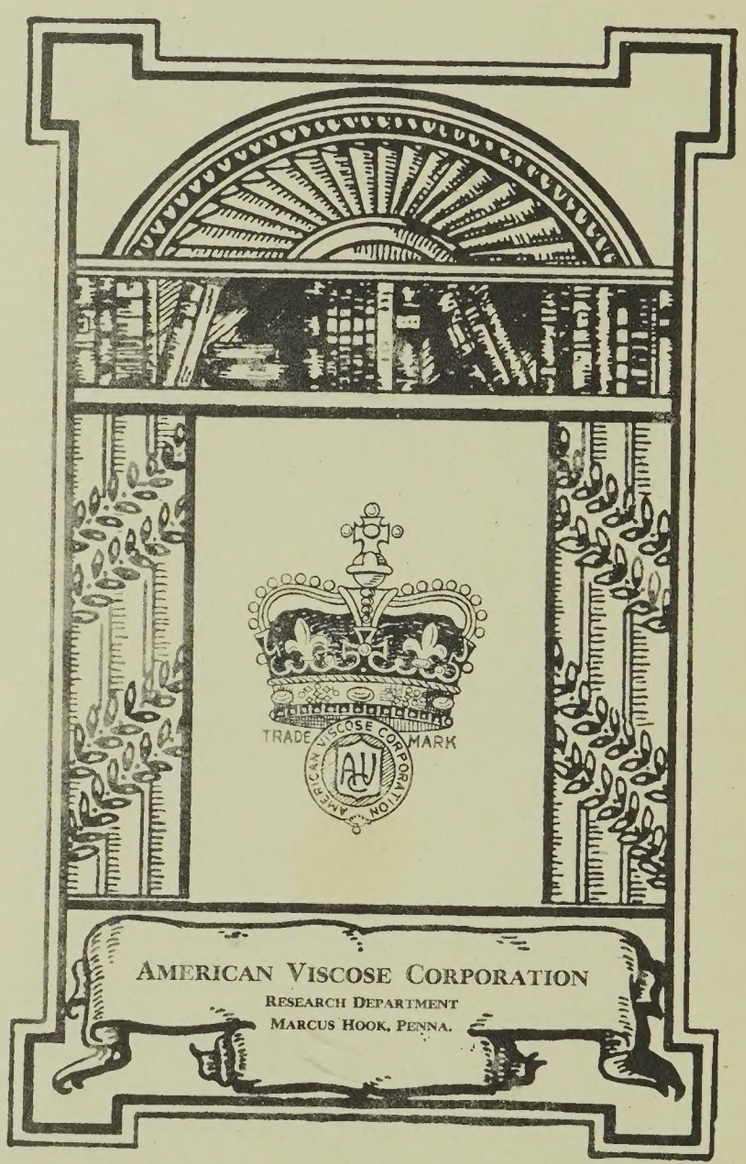

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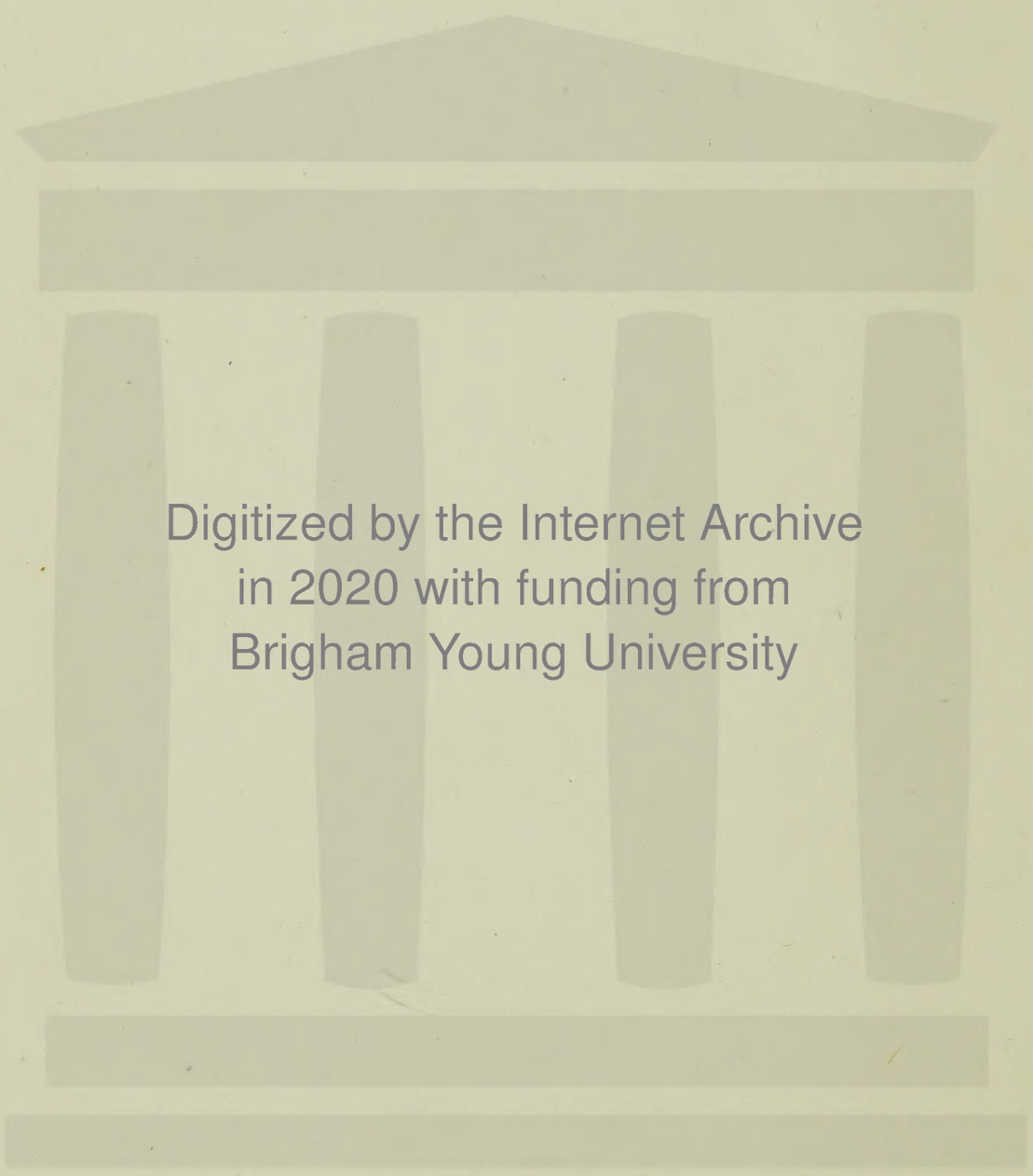

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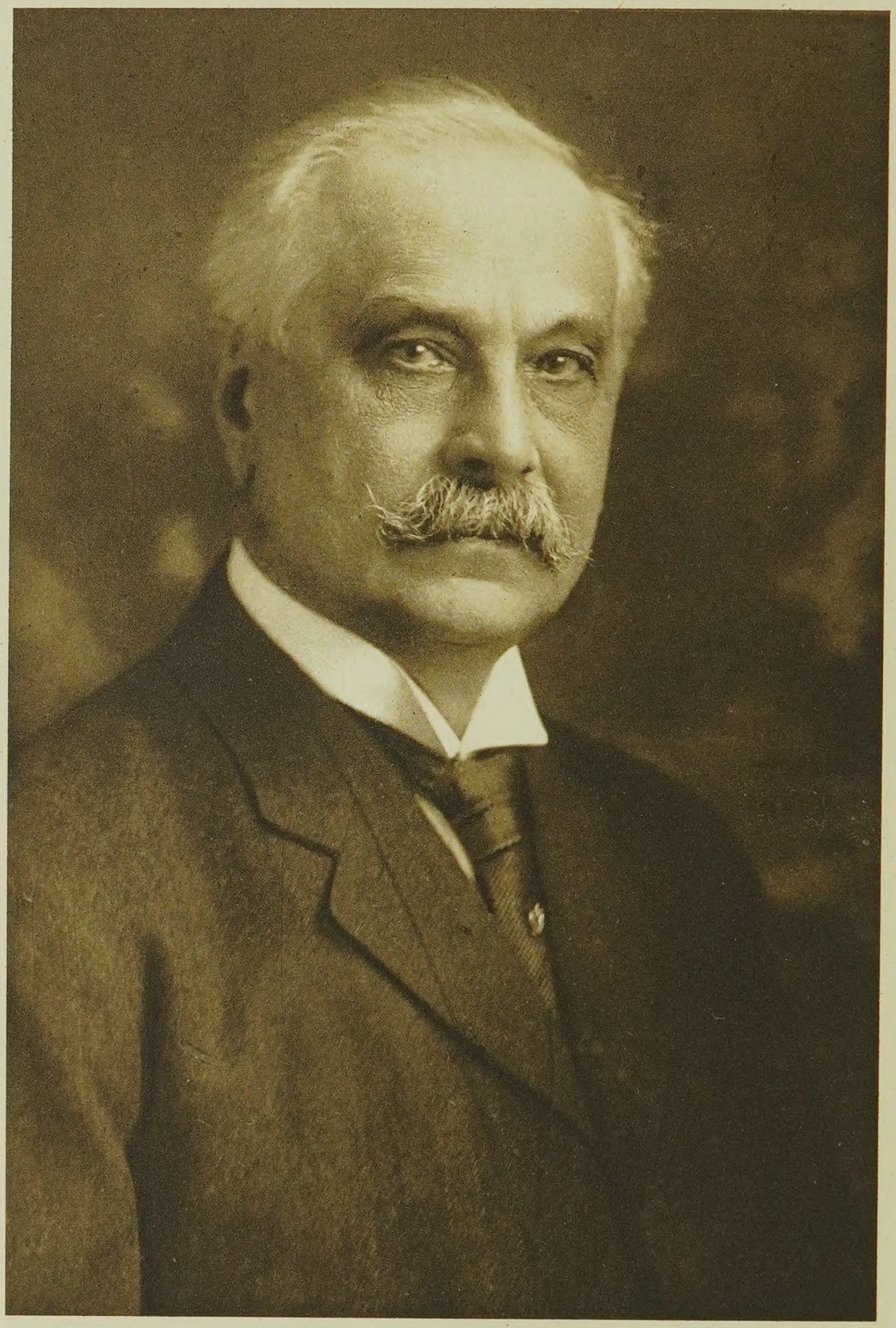

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TRANSACTIONS

OF THE

AMERICAN INSTITUTE

OF

CHEMICAL ENGINEERS

VOLUME III

1910

OFFICE OF THE SECRETARY
POLYTECHNIC INSTITUTE
BROOKLYN, N. Y.

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TRANSACTIONS OF THE AMERICAN INSTITUTE OF CHEMICAL ENGINEERS

SECOND SEMI-ANNUAL MEETING

HELD AT HOTEL CLIFTON, NIAGARA FALLS, ONTARIO,
JUNE 22 TO 24, 1910

MEETING called to order Wednesday, June 22, 10 A.M.

President McKENNA:

It gives me great pleasure to call to order the second semi-annual meeting of the American Institute of Chemical Engineers. We have come from different parts of this continent, some long distances, to meet beside the falling waters, and it is to be hoped that the drone will both comfort us and make us feel as if we were enjoying a vacation, and at the same time be an inspiration for work since it is also a great exhibition of energy. We have, perhaps, presumed a little upon the hospitality of our Canadian members, but they assure us that their welcome is most heartfelt, and to emphasize it they have asked one of their fellow-citizens—one of the most eminent citizens of this part of the country—to voice that welcome for them. It gives me great pleasure to introduce to you Mr. A. Monro Grier, Vice-President of the Niagara Power Co.

MR. A. MONRO GRIER, K.C.:

Mr. Chairman and Gentlemen: Let me start by saying that the advent of the black cat * means, I believe, very great luck for the meeting here. Speaking so early in the morning, it is somewhat hard to hit upon the right theme upon which to talk.

* A black cat ran across the platform.

At the outset let me voice one word, sir, to you and to your colleagues, "Welcome!" Really, having uttered that beautiful sound, everything has been said, and I feel that in a sense, on so beautiful a morning as this, in so exquisite a spot, it had perhaps been more fitting not to go beyond the utterance of that one word. But, as I have been given the honor of addressing you, I propose to say a few words—literally a few words. In the first place, reference has been made to my personality. I think perhaps it would be well that you should feel that the one to whom has been entrusted the honorable task of welcoming you can do so in a sense for all branches of the British race, because I have not the honor of being Canadian born. I have a sincere and abiding affection for the old country across the Atlantic, from which I came some years ago. I have an equally sincere and a very great affection for the land of my adoption, Canada, and I have a great affection also for the United States, since, not only from personal intercourse, but by reason of business association, I know a considerable amount about it for one who had not another honor, namely, that of being born in the United States. When I was asked to speak in this early hour of the day, I wondered if there were any kind of utterance which had been made at any time which indicated what a hard thing it was for a man to have his spoken words considered so early in the morning. And I found that our good friend Robert Herrick, who lived from 1594 to 1674, had said:

> In sober mornings, do not thou rehearse
> The holy incantation of a verse;
> But when that men have both drunk and well fed,
> Let my enchantments then be sung or read.

I must confess for my own part that I should naturally expect a more cordial welcome to words spoken after a good hearty dinner than in the morning after an early breakfast. It is hard to decide of what character they should partake. After dinner one's speech should be of the nature of a mental liqueur—some sort of nice finishing stroke to things which have already been indulged in; but this is absurd in the early morning, after a modest meal of shredded wheat or bacon and eggs. But something can be fitly said, even at this early hour.

It occurs to me at the start—Why am I chosen to welcome you? The reasoning must have been somewhat of a negative char-

acter. I am not a chemist, therefore in that regard a cipher, a negation, a negative. I am not an engineer, therefore in that also a cipher, a negation, a negative. But what do two negatives make? An affirmative. Therefore no one could be more fittingly equipped to welcome you than I am this morning. I am unequipped with knowledge in either department of your learning. I have no civic position here—no illuminated or unilluminated address to present to you. But I really believe that should any of your members by any chance come into controversy with any of the civic population, mayor or police, if you were to say that I vouch for you, you would have the freedom of the city.

We welcome you to what, in my own conception, is a perfectly ideal meeting place. "All work and no play makes Jack a dull boy." This place is ideal as a working place, and it is ideal as a playground, because there is no single emotion which is worthy of being preserved or enjoyed, or increased in any way, which is not helped by the magnificent scenery. And what do you find here? You find that those who play and work here receive wonderful inspiration. You will see what has been accomplished by this wonderful force of electrical energy. Between Niagara Falls and Buffalo you have the opportunity at one and the same time to witness the power plants which develop the energy, and the plants which make use of that work, by electrochemical processes and otherwise. It is a veritable inspiration ground. Think you that it is entirely due to his native abilities that Dr. Acheson has accomplished such wonders here? I do not detract from all the native force, power and faculty of invention which he had. But here he had inspiration to hand all the time, and greater things have been accomplished by him here than would have been possible elsewhere. As an inspiration place it is marvelous. As a lubricant for the mind it is a veritable mental "Oildag."

And I would admonish you to play well whilst you are here. He works best, in my judgment, who plays best. A man of any size of mind realizes that his work can only be well done when his body is well equipped. The old saying "Mens sana in corpore sano"—a sound mind in a sound body—is as true to-day as it was when it was written. Play well; have a good time here, realizing that as you are drinking in health, strength and mental inspiration, you are equipping yourselves better for work hereafter. I need not say work well; I am afraid that you are certain

to do that. I am fearful lest by any chance you should work too well. Do not do so. Do not overdrive the machine in any case, but do take full advantage of the opportunities which you have here, because they are simply wonderful, as I have indicated before.

And now in passing to what you are meeting here to do this morning—your deliberations—may they be very pleasant and profitable. I have said once before, on a like occasion, that, even if it is tolerable in other places that men should be constantly rising to points of order, and otherwise delaying the proceedings, it is intolerable here. The scenery is far too fine to spend any more time than is absolutely requisite for your deliberations. Do not be tender with him who would be willing to thus waste your time. There is a choric song going on outside which is far better worth listening to than things not worth while. Having discussed the things worth while, be done with it and get the inspiration outside. I have in mind an old oriental saying that it takes ten pounds of common sense to carry one pound of learning—a seasonable saying which occasionally is neglected, I think, by men of learning and science, and the hurt is to themselves, and through them to the world at large. I do not know whether this precise measure which I have given you is recorded in your books, but I think it as true as that it takes sixteen ounces avoirdupois to make one pound. In finishing, I have only to say this, that I have tried in what I have said to measure words by weight rather than by number, keeping in mind a saying which to me is fraught with significance, which is, " Keep silence, or else say something which is better than silence." And, immediately, nothing occurs to me which is better from your standpoint than silence, but I take such comfort as I can, when I feel that I am not playing my part well by talking, by reflecting upon that charming utterance, " When I would solace myself with a fool I think of myself, and there I have him."

I welcome you again on behalf of this district and on behalf of this country generally; I welcome you all, from the land across the river or other parts of the world. Naturally our welcome to those across the river is very keen, and I could not ask more on your behalf than that you should be extended as great courtesy while you are here, as I am daily across the river. That is the best that I can hope for you.

Before closing let me offer my congratulations to the members on their great good fortune in their President, Vice-President and other officers who handle their affairs, and I trust that in the history of the Institute you will always have men as well deserving of the honor.

I have said that I am neither a chemist nor an engineer. Speaking from the standpoint of my ignorance, it appears to me that one of the great things in the work of the chemist is fusion; and if I speak of the engineer, the first conception which arises to my mind is of one who makes crooked paths straight. Then, sirs, as those who are lovers of fusion, and of straight ways, (pointing to the entwined Old Glory and Union Jack) I call your attention here this morning to the united flags of the United States and the British Empire.

President McKenna:

I am sure, gentlemen, that you will agree with me that we all owe very much to Mr. Grier for his splendid welcome, and the cordiality of the terms in which he has voiced it. We feel sure that Mr. Grier is no cipher in any sense, that he is in fact *integer vitae* and we are very thankful also for his promise to take care of us if we get into any difficulties with the police or custom authorities on this side of the river.

We will now assume the work of the meeting, and it will be best to begin by receiving the reports of the officers, of the work during the year, that is for the half year so far past.

Secretary Olsen:

I have on hand the report of the Membership Committee, which is perhaps the most important, covering the half year since we met at Philadelphia.

REPORT OF THE MEMBERSHIP COMMITTEE

Semi-Annual Meeting, June 22, 1910.

FOUR meetings have been held since the last report of the Committee at the Annual Meeting at Philadelphia, December 8, 1909.

Twenty-two applications have been considered by the committee; seventeen of which have fulfilled all the requirements of the Constitution and were recommended for election. Three were under age. One was rejected because evidence was not presented that he had done chemical engineering work.

Professor Charles F. Chandler was recommended for honorary membership.

Three Institute ballots were canvassed, 60, 66, and 82 votes repectively being cast A number of ballots for each election were not counted because unsigned. Seventeen candidates were elected upon these three ballots. No candidate was rejected by the vote of the members on the Institute ballot, all candidates which had been recommended by the committee being elected.

The committee spent some time in discussing methods for increasing the membership and securing applications from men who could qualify. For this purpose, the preparation of a confidential list of chemists in the United States who could probably qualify as members and could be invited by members of the committee to make application, has been undertaken.

The preparation of an engrossed certificate of membership was considered by the committee and the following form was tentatively adopted.

This certifies that having qualified by education and experience in chemistry and engineering, has been elected a member of the AMERICAN INSTITUTE OF CHEMICAL ENGINEERS.

Witness our hand and seal at New York this day of

President. Date of Admission

Secretary

An estimate of $85.00 for the printing of 200 certificates has been obtained. As the engrossing of the names of members would cost at least a dollar apiece, the cost of such certificates would not be less than $200 for the present membership.

Respectfully submitted,

A. C. LANGMUIR,

Chairman.

President MCKENNA:

Any motion regarding this report, gentlemen?

Moved and seconded that it be received; no discussion; carried unanimously.

Secretary OLSEN:

Mr. President, the last item, namely the preparation of a certificate of membership, might call for some action. It is a question as to whether the Institute wishes to have it done at the present time, more particularly on account of the expense. It is a question whether the Institute will bear the expense of $200, and another question as to whether you would like to make a charge to the members for the certificate.

Mr. RENAUD:

I think it might be wise to make a charge, and suggest that the charge be $5.00.

It was moved and seconded that the membership certificates be charged to individual members at the rate of $5.00.

Dr. WIECHMANN:

Make it $2.00.

Mr. RENAUD:

I had in view the making of revenue. If the object is merely to pay for the cost of the certificates, then make it $2.00.

In regard to the form of the certificate; it says, "Witness our hand and seal." I would like to ask whether the Institute has adopted a seal; if not, would it be proper to adopt a seal?

The motion with regard to certificate was amended, making the charge $2.00, and carried as amended.

President MCKENNA:

About the seal of the Institute, I shall bring up that subject in a few minutes.

Secretary Olsen then read the report of the Committee on Medal.

REPORT OF THE COMMITTEE ON MEDAL

It is proposed to establish a medal to be termed "The American Institute of Chemical Engineers Medal." Correspondence with members of our committee shows the general desire to be for a permanent foundation of $1000 or $1250. The income of this sum shall be expended annually or when considered expedient for a medal to be awarded to any person presenting the best original paper to the American Institute of Chemical Engineers upon a chemical engineering subject.

The specific terms of award shall be arranged by a medal committee.

With the advice and consent of the Council it is desired to begin collecting funds for this purpose at once from members of the Institute, large corporations dealing with applications of chemistry and friends interested in the advance of chemical engineering education.

All contributions are to be voluntary.

It is suggested that funds be collected by special subscription for an award to be announced at the next annual meeting in December. It is desired to raise $40 or $50.

Such interest as shall accumulate upon the sum raised for a permanent fund shall be thereafter applied to the purchase of a medal subject to the regulations of the committee.

All funds collected for this purpose shall be placed in the hands of the treasurer who shall deposit these with a reputable bank or trust company under separate account to be termed "The Medal Fund," American Institute of Chemical Engineers.

WM. M. BOOTH,
Chairman.

President McKENNA:

Gentlemen, we will pass upon the acceptance of this report and then take up the terms item by item.

Moved and seconded that the report of the Committee on Medal of the American Institute of Chemical Engineers be received.

Carried.

President McKenna:

The members might like to take up for consideration the specific suggestions. There should be a vote taken either upon the carrying out of all the suggestions, or, if the members prefer, each item of the report might be taken up. I will begin in the latter way and see if it pleases you:

"There shall be established the American Institute of Chemical Engineers Medal."

Does that receive the favor of the body here? (No dissent.)

"The permanent foundation shall be $1250."

Dr. Sadtler:

I think in a general way that we are all agreed that the establishment of an Institute medal would be very desirable. The awarding of medals by the older societies—the Mining Engineers and the Iron and Steel Institute—annually, is so important for the reputation it gives a man, that it is eagerly waited for throughout the entire year. I believe it would be one of the great elements that would help to develop sound minds in the Institute. A medal of proper value to be awarded each year to young manufacturing chemists and chemical engineers would encourage them to take up some special line of work particularly with a view to gaining that medal. Whether or not we should establish a definite foundation for it is a premature question. My first thought about the medal was that we might temporarily carry the expense and award of a medal, looking forward to some friend who has been interested in chemical industry, taking this up as a privilege and giving us a fund for this purpose. I do not refer to Carnegie, or somebody who has been prominent before the community. He might possibly establish a larger sum, and the medal might have a value of $100 in cash, besides the usual testimonial. The idea of the committee was to raise $50, perhaps, until we could get a permanent foundation. We would not want to limit the amount now, and I would move that it be subject to adjustment later. I think all of us agree that a medal, even on a temporary basis, is desirable. I would be very glad to know as to whether that view is held by others in the Institute.

President McKenna:

At our last Annual Meeting this subject was discussed, and there were at least five members, and I know that number could

easily be doubled, who said that they would be very glad indeed to be called upon early each year for a subscription to meet the cost of the medal for that year. This is a feasible proposition in case we do not care to establish the form of the medal, and secure an expensive die. The first cost of a die, I imagine, would be very large. If the honor was awarded, and only a temporary form of medal, this subscription of a few members would do very well, and the project can be carried until the generous patron arrives. I think a motion would be in order, Dr. Sadtler, if you expect to advise some scheme by which subscriptions should be received for a temporary fund, that the award of the medal be authorized at the end of this year, and that the financial problem be solved by passing the hat.

Dr. SADTLER:

If it is in order. Mr. Chairman, I would move that the members of the Institute here approve the institution of such a medal, as a temporary matter, and that they authorize this Committee on Medal to receive subscriptions for defraying the cost of the temporary medal, and that it be published for next year.

President MCKENNA:

Should it not include the year 1910 for papers read at this meeting, and the December meeting?

Dr. SADTLER:

Yes, very desirable.

The motion was seconded by Dr. Wiechmann, and carried unanimously.

Secretary OLSEN:

I would like to make one remark. If the medal should be given for papers read at this and the December meeting, it could not be awarded at the December meeting. It would be awarded at the Summer meeting a year from to-day. There is a whole year to collect the money and prepare the medal.

President MCKENNA:

These remarks upon the medal will be sent to the Medal Committee for their guidance, and the specific terms of the award can be arranged by the Committee.

Dr. SADTLER:

I think the Medal Committee should bring in some kind of a

scheme for receiving the papers. It seems to me that we ought to limit the competition to papers presented here at the meeting. It might be that someone would work up a very nice paper and present it to the committee. These papers ought to be received under rules and regulations made by the Medal Committee.

President McKenna:

The instructions of this meeting to the Medal Committee are that the papers presented to this Institute as well as other meritorious ones in chemistry throughout the country, should be considered as of the year 1910, to be awarded in the year 1911.

Dr. Wiechmann:

For any society in the United States?

President McKenna:

I would like to have the views of the members on that point. I think it would be very well to have a ruling as to whether you would amend the report, which now reads "Medal to be awarded to any person for a paper upon a chemical engineering subject," by inserting there, "presented to the American Institute of Chemical Engineers." I think it would be a very wise thing to settle this matter in one way or another now. The remaining points can probably be left for discussion and determination by the Medal Committee, which, while an annual committee, it is hoped will remain the same in personnel from year to year as far as possible.

Dr. Sadtler:

Has authority been given to the committee to prepare regulations?

President McKenna:

Yes. The committee is to prepare definite regulations, and take charge.

There is one other regulation which it would be very important to determine now, and that is, that we should define the duties of the committee in this award. Would it not be a very desirable regulation that the Medal Committee shall consider the subject of an award each year, and submit a name to the Council for ratification? If that is the sense of the members present, I think we can accept it as a vote.

Dr. ACHESON:

Do I understand that the competition is not necessarily for members of the Institute only, but simply for papers presented to the Institute?

President MCKENNA:

An original paper presented to the Institute.

Dr. WIECHMANN:

By members and non-members?

President MCKENNA:

Yes.

Dr. ACHESON:

While, of course, we would like to have the papers presented to the Institute, it has been my personal experience that it frequently happens that you have an important matter which you want to present publicly, and that it is a hardship to have to wait several months for the convening of a Society.

President MCKENNA:

I would suggest this remedy, if this meeting approves of it, that the paper be presented to the Secretary as a matter of record, that is, that the first original presentation of the subject shall be recorded with the Secretary.

Dr. SADTLER:

My conception of the Institute is that it is larger than an ordinary society, and it should not be necessary for a paper to be held in abeyance until we have a meeting.

Secretary OLSEN:

The report says "presented" not "read." A man should send in his paper and say that he wanted it considered. We should receive it and publish it in the Transactions. It is important that it should appear in the Transactions.

Mr. CAMP:

After presentation to the Society could the paper be published in other papers?

President MCKENNA:

Yes, of course he may then publish it.

That is another point of instruction to the Committee on Medal.

Secretary Olsen:

I wish to state that the Treasurer's report is promised, but has not been received by the Secretary as yet.

REPORT OF SECRETARY

The Secretary considers it his first duty to take care of applications, and to secure as many new members as possible. He is pleased to report that seventeen applications have passed through his office on which he has received proper references and information for the Membership Committee, so that they have been able to pass upon them, and make recommendations for election. In carrying out that duty, I want to say that we lose many good applications because our members are not quite as careful as they should be. I find that many men are ready to say yes, they will join the Institute, it is a good thing, but when they see the application blank, and that they must put down all the facts of their career, they rather hesitate. If a member takes the application blank, and says, "Give me the essential facts—date of birth, where were you educated, what important positions have you held," and then puts down the references which will cover that period, it is not so formidable. It is the duty of members to get the essential facts of the career of applicants without paying too much attention to red tape. All that the committee desires is good and sufficient evidence of education and training, and that the applicant has held responsible positions, and has the proper references.

The general correspondence of the office during the last six months involved sending out about 3000 pieces of mail.

The membership badge was finally prepared and orders are being received continually for new badges. The company which is making these badges succeeded after considerable trouble in giving us the right shape and color, and is engraving the member's name and number on the back.

Dr. Sadtler:

May I ask how many have been delivered?

Secretary Olsen:

Something like sixty. About half of the members at the present time have badges. I might say that one member who

purchased a badge has since sent in his resignation. He has the Institute badge, but has resigned as a member.

A bulletin was issued from the office immediately after the last meeting, and the Secretary desires instruction as to whether this should be continued. The bulletin gave an account of the Philadelphia meeting, and included twenty-two pages. The cost was something like $40 or $50.

The second volume of the Transactions has been published through the Secretary's office during the past six months. Some of the papers were very easily handled; they had merely to be sent to the printer. Others required hours and hours of strenuous labor, and consequently I should like to request that members be careful in this respect. If there are illustrations the references to the illustrations should be carefully made, and they should be numbered. I would also request that the English and other features of the papers be carefully looked after, and when discussions are sent in they should be edited by members, so that there is no duplication. This second volume of the Transactions is promised for to-morrow; that is, a sufficient number for the members present at the meeting, and, of course, if any non-members desire to secure a copy they may do so. This is three months in advance of the publication last year, when the volume appeared in August or September.

A new membership list has also been published through the Secretary's office, and is on hand for members who desire a copy of the same.

J. C. Olsen,
Secretary.

President McKenna:

I wish just now to say that we have several topics of great importance to the welfare of the Institute which cannot all be taken up this morning, and I was a little afraid that they might develop into great time consumers, so that we would not have time for the papers. Some of them are matters for the Council. While such a discussion is not strictly necessary, these topics are vital for the future welfare of the Institute. Such a topic would be the incorporation of the Institute. We have not as yet received or applied for legal incorporation of this body. It has not been necessary. I think that some of the members here will tell us that it is quite necessary now, and I will now bring

this subject before you for discussion. Shall the Institute obtain legal incorporation?

Mr. RENAUD:

With regard to the incorporation of the Institute, I have had recently to look up the law with regard to that point. At least thirty-two days' notice is required according to the laws of the State of New York. If incorporation is sought by the Institute motion should be made to that effect, and notice sent to the members thirty days before the next annual meeting. After that action can be taken and not before.

President MCKENNA:

Mr. Renaud is a "limb of the law," an attorney at law as well as a chemical engineer, and knows the law upon this subject. I should like to ask him to give us the reasons for incorporation. I will then ask if any of the members see any reason why we should not be incorporated.

Mr. RENAUD:

The reasons for incorporation are many. I know none against it. One of the reasons for it is that it takes all the liability from the individual members of the Institute. At the present time, as I suppose most of us know, each and every one of us is liable for all debts and actions of the Institute, including money damages. I noticed in looking up the records of the American Chemical Society, that after they had been in existence for about a year and a half, they tried to hire a hall for a meeting in New York City, and were unable to do so until they were incorporated. They proceeded to incorporate their society. In the matter of copyrights, I am inclined to think, as I remember the law, a copyright is granted only to an individual, or an incorporated institution. The copyrights of this Institute now should be made in the name of the Secretary. With regard to obtaining stamped envelopes from the government, they are not issued to any unincorporated organization. The incorporation also gives the right to have a seal, and to be recognized as a legal entity, to sue and to be sued. It also reduces the danger of competition in name. If the Institute is incorporated and the name is registered in the Secretary's office at Albany, no similar name can be used. These are the only reasons that I can think of offhand.

President McKenna:

I imagine that there would be very little reason for not incorporating, and think a motion is needed now to prepare for the formal notice.

The motion was made that the notices be sent out.

Dr. Acheson:

I would like to ask, Mr. President, if you refer to incorporating the Institute under the laws of the State of New York. Should it be a state institution?

President McKenna:

That does not figure as important, I think. It can be taken up in any state in the Union.

Mr. Renaud:

There is no way of incorporating federally, except by an act of Congress. You could have such an act passed.

President McKenna:

Is there any advantage in federal over state incorporation?

Mr. Renaud:

None that I know of.

President McKenna:

It is moved and seconded that notice be formally served on the members of the Institute of the bringing forward of the subject of incorporation, the notice to be sent out thirty days previous to the annual meeting.

(Carried unanimously.)

The related question then, is as to the seal of the Institute, and, of course, it goes without saying that we will obtain a seal and use it. I do not suppose there is any necessity for the discussion of the form. The Secretary would be empowered to get designs and submit them

The place for the next meeting is quite important. We have had under consideration for a period of six months the holding of meetings in succession at Niagara Falls and St. Louis, Mo. Taking the views of all the St. Louis members showed the officers that a meeting at St. Louis would not be eminently successful. The attendance would not be at all large, the number of valuable factories to visit would not be very great, and those that would

be open to us would not be very important. A number of the St. Louis members assured us that they felt a little timid of the success of such a meeting. The next place to consider is Chicago. Some of the same difficulties occur there. If this meeting were to take the views of the officers, who have gone over the matter very carefully, they would agree that a city like New York or Philadelphia for the present offers the best chance of a large, well attended, and professionally important meeting; one at which numerous plants will be open for inspection, giving a wide variety of technical work to view. And I know that the New York members are very anxious to welcome the members of the Institute again. They would not come forward with this invitation, by reason of their fears of being considered to desire to have the meeting too easy for them, were it not that they feel that a good, large meeting could be held in New York, and they are very glad indeed to act as hosts. There may be other cities within reach of a fair share of our members which would serve better. This subject is now before you. Views upon the subject of the place for the next meeting are welcome.

Dr. LINDER:

I would like to ask how many members of this Institute live west of here.

Secretary OLSEN:

In planning for the train to come to Niagara Falls, I found that the Lehigh Valley could take at least fifty members while our total membership is one hundred and twenty. Of course all the members in Philadelphia, New York, New Jersey and Connecticut could come to New York. If you drew a line through Pittsburg you would have perhaps ninety per cent of the members east of that line. The center of residence of our members would probably be somewhere around Philadelphia.

Dr. SADTLER:

This matter of place of meeting is a very important one for the Institute, and I am agreed with the Chairman that it would be well to have the next meeting in New York. But I think it is very desirable in the near future to find a Western point at which to hold an annual meeting, so as to strengthen the Institute in our great central western territory. Cleveland, St. Louis and

Chicago should be considered in the future. I do not think we have any members in Cleveland and only four in Chicago. The St. Louis members have been asked twice, and each time they have said that they are not quite ready. We are rather tied up to these two cities. The last meeting was in Philadelphia and the next will be in New York for that reason. The year after that we ought to move into the west, and see if we cannot have twenty-five or thirty new members from the central west. It is very desirable to strengthen the Institute, and make it something more than a little group of men here in the East.

President McKenna:

If there is no objection, the officers will consider that there is a recommendation, if all can be arranged well, for a meeting in New York.

Dr. Sadtler:

There are two more important things to consider: Junior Membership, and as to whether ex-presidents ought, say for a term of two years, to be members of the Council. I was elected a member of the Council, and feel that I kept someone else from being elected. I think we ought to have the full elective on the Council and that for two years the ex-presidents should give the Council the benefit of what they have learned during their term of office.

Mr. Camp:

The Engineers' Society of Western Pennsylvania has made a rule that ex-presidents are ex-officio members of the board of directors—for one year, I believe it is in their case. If it is in order, I would make a motion to the effect that ex-presidents shall be ex-officio members of the Council for two years

The motion was seconded by Dr. Sadtler.

Secretary Olsen:

Mr. President, an amendment of that kind was regularly proposed at our last meeting, and you will find it in the February bulletin. According to our Constitution it must be discussed at this meeting, and after this meeting a letter ballot will be taken for final decision as to its adoption.

Motion withdrawn.

President McKenna:

The method of getting the business of this semi-annual meeting

transacted, will be to steal the time from papers and other subjects. We will leave the question of amendments for future discussion. But this matter of ex-presidents being members of the Council can be taken up now, and closed at this meeting. As the Secretary has told you already, it has been formally put in print, and it is for this meeting to discuss it. I myself do not know how it works in other societies. I had a notion that two years was rather a limited term.

Dr. ACHESON:

Two years is the term in the American Electro-Chemical Society.

President MCKENNA:

It will be taken as the recommendation of this meeting that the amendment as to ex-presidents finds favor.

The other two proposed amendments and questions of finance will be taken up when we find time, that is as the reading of the papers develops leisure for it.

There is one recommendation made by the Membership Committee which the Secretary did not read. It is not in their formal report. They have made a recommendation that complimentary copies of the Transactions of this Institute be presented to the library of the Polytechnic Institute of Brooklyn. We have enjoyed the hospitality of the Polytechnic Institute on numerous occasions during the last two years. Moreover, there are other good reasons why the courtesy of free copies should be extended to the library of the Institute. One of these is that it is a very excellent library, often consulted by chemical engineers, and it may help the work of the Membership Committee.

It was moved by Dr. Wiechmann, seconded and carried, that complimentary copies of the Transactions of the Institute be presented to the library of the Polytechnic Institute of Brooklyn.

Secretary OLSEN:

I wish to thank you on behalf of the Polytechnic Institute for the favor you have tendered. We shall always stand ready to welcome you and to serve you in any way possible, as we tried to do a year ago when you held your meeting there.

President MCKENNA:

Dr. Haanel has an invitation to extend, and I will ask him to announce it himself.

Dr. HAANEL:

Mr. President and Gentlemen of the Institute: There will be a meeting of the American Peat Association on the 25th, 26th and 27th of July in Ottawa, and I would myself heartily invite the members to visit us at that time. I prevailed upon the government to allow me a boat for the purpose of entertaining the members of the Peat Association and their guests. The program is to be an exceedingly interesting one. I shall take the members and guests out to the peat plant by special train. We will also have an automobile ride throughout the whole of the surroundings of Ottawa, and we will have a banquet at Ailma, all of course at the expense of the government. I shall be very glad indeed, if you are interested in our special peat gas producer plant, if you will avail yourselves of the invitation and come to Ottawa to see us.

President MCKENNA:

Would the plant be open to members if they went on Saturday of this week?

Dr. HAANEL:

If there are any members of the Institute who desire to see our peat producer plant in Ottawa, and if you will let me know how many are likely to visit the plant on Saturday, I will telegraph to have the plant in operation.

President MCKENNA:

If members wish to take advantage of this very excellent opportunity to see the very latest development in the use of a hitherto despised, but now very important fuel, they will please acquaint Dr. Haanel with their desire, so that a special party can be gotten up.

The following papers were then read and discussed:

The Changes in Industrial Chemistry caused by Electricity. Edward R. Taylor.

Notes on the Corrosion of Iron and Steel and its Prevention. G. W. Thompson.

A New Product for Use in the Arts. F. G. Wiechmann.

Commercial Calcium Hydrate, Its Manufacture and Uses. Lucius E. Allen.

Meeting adjourned.

Wednesday Evening Session

Address by President McKenna—The Study of Materials as a Subject in a Course of Chemical Engineering.

Report of the Committee on Chemical Engineering Education. F. W. Frerichs.

Friday Morning Session

Reading of papers.

Chemical Industries of Canada. J. A. DeCew.

The Manufacture and Industrial Applications of Ozone. Oscar Linder.

Problems in Chemical Industry. J. T. Baker.

Commercial Manipulation of Refractory Elements for Incandescent Lamp Purposes. Ralph E. Meyers.

Friday Evening Session

Reading of papers.

Underground Waters for Manufacturing Purposes. Wm. M. Booth.

Loss in Coal due to Storage. A. Bement.

Nitric and Mixed Acids. Schuyler Frazer.

Plant Design. Wm. M. Grosvenor.

President McKenna:

I have several questions to present, either to a vote or for direction, and we have also amendments to the constitution to consider, although you have no vote upon them at present. The vote will be by mail.

The officers would like direction regarding the policy to be observed with reference to the exchange of Transactions. We have been asked to exchange our volume for the weekly and monthly scientific publications of other societies, and there is a question as to whether we should or should not do this, on account of the expense to us of getting out what is only one volume a year. I will ask the Secretary to explain the situation with regard to this question.

Secretary OLSEN:

I receive quite frequently requests to exchange publications. We have acceded to several of these, and we consider that it would be to the advantage of the Institute to have our transactions on file in the library of other societies. We have already acceded to the request of the Society of Mechanical Engineers and also to the request of a Society in the west with headquarters at Denver. I received a request from the Department of Agriculture for Transactions and replied that we could not exchange. They purchased a copy, and I have on file their order for subsequent volumes. In addition I have received a request from the Bureau of Standards in Washington for exchange. This request is still awaiting action. The requests come in continually, and I am in a quandary to know what to do—whether, in the case of the Bureau of Standards, to grant their request, whether action should be taken on each one separately, or whether a general rule should be made.

President MCKENNA:

I would suggest for consideration having a Committee on Library, although it is not likely that we would desire to own a very large library, but we may not desire to pass title to what we do have. We may wish to store it with a good chemical library. I am very much devoted to seeing a success made of the Chemists' Club library. Having received the publications, in exchange they might extend to us the courtesy of a shelf or shelves kept exclusively for our property. If we had a library committee a library of anything from one to one thousand volumes could accumulate, and discretion could be left to that committee.

Secretary OLSEN:

There is one provided for in the constitution.

Mr. TAYLOR:

If it is in order, I would move that a Library Committee, such as suggested, be appointed to have such matters in charge.

My judgment is, speaking aside from the motion, that we would do well in exchanging for the United States Government publications. There is no source of information so free to our people as the publications of the United States Government, and I think

we can well feel it an honor to contribute our publications. I make that remark aside from the motion.

Dr. SADTLER:

In seconding the motion, I would like to call attention to one feature briefly referred to. It is not so much the fact that we get so much of value in exchange. We are a young society, and our prestige is not yet established. In my opinion there is no better way of establishing it and getting to be known than to have articles quoted and referred to by authoritative societies. If giving the Transactions in exchange will cause the papers to be referred to by large numbers of standard societies, and by authors of papers and publications, it will help a good deal. It will give us a standing of the same character as that already held by such societies as the Society of Civil Engineers, Institute of Mining Engineers and so forth. It is a very good way of taking such rank, that of having the volumes referred to as the repository of valuable papers. It will lead to inquiries of all sorts. I think it a very excellent idea to get our publications distributed in the best circles in that way.

President MCKENNA:

The second volume of the Transactions will be delivered to you within a very few days. We had hoped to have the first score of volumes sent here to-day. They have not arrived as yet, but they are all printed, and in the hands of the binders. We will have them inside a week. This volume is fifty per cent larger than volume one. I will put this motion of Mr. Taylor to a vote.

Motion carried unanimously.

President MCKENNA:

Another question before us is, shall a Bulletin be issued, either regularly, or authorized for the time succeeding this meeting—one similar to the one issued after the Philadelphia meeting? It would probably contain the report of this meeting, and a number of papers if they were found by the Committee on Publications to be ready and without any necessity for change. Dr. Wiechmann, particularly, I think, should have the credit and honor of having his paper published as early as possible, because he has delayed it a long while for the sake of presenting it to

the Institute first. It is a public announcement of a discovery of value, and ought, in justice to him, to be printed as soon as possible. That can be a part of this bulletin, together with a proper report of this meeting, and a fair report of discussions of important topics. We must keep our members fully informed of the progress during the year. If they have to wait for the annual volume it may be a disappointment, and I have a notion that the last bulletin was favorably received for that reason. The cost was only $50. Probably the next number would cost considerably more because the material would be much greater, and the number of copies somewhat larger. The question is then before you—shall a bulletin similar to the last be issued?

Dr. GROSVENOR:

Is it not a fact that a large proportion of the cost of such a bulletin as is suggested would be, practically speaking, deducted from the cost of the Transactions when they are printed?

President MCKENNA:

That is the plan, and it works out fairly well, I believe. Of course some of it is a little more airy and discursive than is necessary for the Transactions. It is rather for informing the members of the proceedings at the meeting and the amusements which are provided for us.

Mr. MINER:

It seems to me that we owe it to the authors of these important papers, and we certainly owe it to members who are not able to attend this meeting, that such a report should be issued in bulletin form at as early a date as possible, and, in accordance with the suggestion, I move that authority be given for the issue of that bulletin.

President MCKENNA:

Motion carried.

I have marked down as a subject for brief discussion the condition of the finances of the Institute. The Treasurer's report will first be given.

REPORT OF TREASURER, JUNE 18, 1910

Cash in bank Dec. 10, 1909	$401.55
Membership dues	916.40
Vol. I (includes sales by D. Van Nostrand)	158.10
Proceeds dinner, Philadelphia	102.05
Badges	10.50
Interest	7.94
Total	1596.54

DISBURSEMENTS

Secretary's office		$154.99	
Treasurer's office		10.50	
Transactions Vol. I		575.58	
Expenses Philadelphia meeting:			
Stenographer	$46.50		
Prof. Munroe	14.80		
Dinner	102.05		
Programs	13.84		
		177.19	
Bulletin		61.39	
Miscellaneous printing, etc.		77.72	
Exchange		5.10	
			1062.47
Cash on hand June 18, 1910			534.07

Respectfully submitted
W. M. BOOTH,
Treasurer.

Secretary OLSEN:

That is $534 on hand at the present time, and inasmuch as the treasurer collects dues semi-annually, there will be $7.50 from every member for the second half of the year, and with 120 members you can figure yourselves that that will amount to $900, which, plus the $534, will give something like $1434. The expenses are as follows:

The Transactions will cost about $1200—that is for one volume. The cost of the first volume is paid, but the second volume, which is now practically issued, and which I hoped to have here at this meeting, will bring in a bill of another $1200, which must be paid out of this year's funds. This meeting, of course, involves some expense, which I think will not be over $75, while of

course the expense of the Secretary's office, which the Secretary endeavors to keep as low as possible—postage, stationery and some stenographer's assistance—amounts to something like $20–$25 a month, or for six months about $150. That will add up to about $1425 for the balance of the year, with a probable income of a somewhat greater amount.

The first volume of the Transactions has had a fairly large sale. We have sold at least fifty, but the Society does not net $6.00 on account of the contract with the publisher. Most of these net only $3.00. Our publishers present a bill which is the net cost of printing, binding, paper and plates, without any profit whatever in publishing. The services of their men are given without charge. In consideration of this they have the sale of the volume, and pay us $3.00 for every one sold, so that the profit to us from the sale of the first volume has been about $150, and the sale of the second volume will probably net us quite as much and possibly somewhat more—probably $250. $200 or $300, I should think, ought to be the balance in the treasury at the end of the year, which is not counting on any great increase in membership during the next six months. The increase during the first six months has been seventeen, and there is no reason why we should not have a much greater increase during the second six months, and close the year with all bills paid, and a fair balance in the treasury.

President McKenna:

I do not think that is at all a healthy report. I think it would have been better to have reported a deficit.

Mr. Taylor:

How many volumes of the first Transactions have we on hand at present?

Secretary Olsen:

We printed 500 and bound 300. The membership received about 100 volumes at that time. We have presented complimentary copies to various technical journals, which might amount to 20–30 volumes. Then the volumes sold may bring it up to 200 volumes, which would leave us with 100 bound and 200 unbound copies. We also have the plates from which these are printed, so that at any future time we could print additional copies.

Mr. TAYLOR:

Would the type have to be reset?

Secretary OLSEN:

No. We can print from the plates.

Mr. TAYLOR:

The American Electro-Chemical Society have found a very great advantage in having back volumes. They have sold for a considerable sum, and are apparently a source of excellent income to our Society at the present time. The first two or three volumes are now exhausted, and in this way they have a fund from which they can reprint them.

Secretary OLSEN:

The storage of printed volumes is very expensive, while plates can be easily stored. Press work from plates is also considerably cheaper than printing from type because the handling of type is very expensive.

Dr. SADTLER:

Has the Secretary had the opportunity yet to make a thorough canvass of the public libraries of the more substantial character throughout the country—not simply college, university and technical school libraries, but general reference libraries? I believe if that canvass has not been very complete it might be followed up to advantage by a second and more complete canvass, and it must be remembered that now we have two volumes to our credit instead of one, and consequently have a much stronger argument to present. As our organization becomes better known we shall get more favorable replies, where we hardly expected to do so at the start. I do not see why we should not sell five times fifty copies of volume one to libraries all over the country, and of course that holds equally true for subsequent volumes. That will mean ultimately a very steady and satisfactory income for this organization. I know that this is so with the American Electro-Chemical Society, because I am familiar with the inside working of that organization. Prof. Richards has been very arduous in circularizing the libraries.

Secretary OLSEN:

I believe that the D. Van Nostrand Co. have printed 15,000 circulars. I cannot say that all of these have as yet gone out,

but know that a batch of 4000 or 5000 went out in the beginning. They form a very excellent advertisement. They obtained a membership list of the Society of Chemical Industry, and I believe that circulars to that list have gone out.

Dr. SADTLER:

I would suggest circularizing the libraries direct. A personal letter will more likely be referred to the library committee.

Secretary OLSEN:

How many libraries do you think I should circularize?

Dr. SADTLER:

Three or four hundred. Enclose both circulars with the letter about the second volume.

President MCKENNA:

A subject which will be brought up before the officers in due time is one which should be presented here, so that the opinion of the members present may be taken, and reported to the officers. It is an important subject, and that is the beginning of the payment of compensation to the Secretary. The mere introduction of the subject is sufficient to start a discussion. I have no views on the subject as to amount. I only know that we have a hard-working Secretary. I know that he has devoted his very strength to this movement regardless of his own duties to himself and others. He has been untiring, and we can tell by the results of his work what he has done in hours and times that we do not see him, and therefore I place before you the question: Shall we compensate our Secretary, and how shall we compensate him? He is as ready as ever to make sacrifices for the Society, and this is only a question of mere justice. The salary need not necessarily be very liberal.

Mr. TAYLOR:

I have very positive views on that subjecct. I think our hard-working Secretary should be paid, and I think it is safe for us to leave it to the officers what his salary should be. Also, I think it would be wise to employ an assistant for him to such an extent as may seem desirable, especially to the end that the publications should be gotten out as quickly as possible after our meetings. Promptness in getting out our Transactions is very important in our work.

I move that the Secretary be compensated for his services, and that the fixing of the amount be left to the officers.

Motion seconded by Mr. Baker.

Dr. SADTLER:

Motion amended to the effect that the subject be referred to the Council with the favorable opinions of the members.

President MCKENNA:

With regard to bringing out the Transactions, I would also say that the Secretary has improved matters very materially, and a favorable result of our action in this matter to-night is going to make them still more satisfactory.

Motion as amended carried unanimously.

President MCKENNA:

We have only before us, then, the matter of amendments to the constitution. We have passed upon the amendment providing that ex-presidents be members of the Council. The second is the one providing for junior membership, and the third, the payment of initiation fee after January 1, 1911.

Amendment with regard to admission of junior members read by Secretary.

President MCKENNA:

Unless some gentleman wishes to express views in dissent, I shall report in the proceedings that the body here to-night favors this amendment unanimously.

No dissent.

We will take up next the subject of the amendment of the constitution with regard to the initiation fee. The amendment simply consists in substituting for the provision of the constitution as originally adopted (the provision that no initiation fee shall be charged until the membership shall reach 200), a provision that an initiation fee of $15 will be charged after the first of the year 1911.

Secretary OLSEN:

If I might be allowed to express my views, I would like to say that in my opinion our finances are in a sufficiently satisfactory state. We have a surplus, and our President has said that a deficit is better. I want to say that I consider 200 members

of more importance than the $15 which the men who come in after January 1, 1911, may pay. We are a new organization, and there are many men who have been in the profession a long time whom we desire to have as members. They will benefit us and we will benefit them. They are paying dues to a great many societies. If entrance to this Society means the payment of $30 I think it will act as a hindrance. Most societies do without initiation fees until they have reached a considerable strength in numbers. I think 200 is a very reasonable number to set. I think we shall get more new members without the fee, and make up for any paltry $15—paltry compared with members.

Dr. SADTLER:

I agree with Dr. Olsen. I think we had better get in a number of excellent men that we know of, and raise our membership to 200 first. The reason is, not that they are too poor to pay the $15, but simply that they are actively interested in a number of other organizations. I tried a couple of years ago to cut down my membership list, because it is a drain on a man to pay membership dues to five or six societies and a club besides—a considerable drain, and I think we shall get the men we want better by holding off.

Mr. TAYLOR:

I move that the resolution be laid upon the table.

President MCKENNA:

I shall report the sense of the meeting when the circular goes out asking for a vote that the amendment proposed regarding a change of date for the payment of initiation fee does not find favor at this meeting.

I hope you all feel disposed to give a little more time to the affairs of the Institute. I should like to express my extreme satisfaction at the result of the call for this meeting. I am not speaking only from my own personal experience when I say that it is one of the pleasantest that has ever been recorded in our circle, and it has been successful as well as pleasant. One lesson we should learn is to continue our efforts, and to continue also to speak of the Institute with a modest but at the same time strong tone to those we meet who are inquiring after it with a view to entering. And a lesson also to learn is that at the next

meeting, which will be the annual meeting, every member should make the utmost endeavor to be present, and to write at an early time when he has learned of the date of the meeting to his friends among the membership to make certain that his particular group of friends are coming. Lastly, there is little that can be done more conducive to the pleasure and satisfaction of a meeting than to have the company of the ladies. This is a small society, and we can very easily take care of a few of those fair delegates and it will add to the pleasure when we gather together on those evenings or days.

The local committee at the next meeting I feel sure will make every effort to prepare a program of excursions, which will be conducted in the ideal way in which Dr. Acheson to-day assisted us to conduct ours, where some provision will be made for the comfort of the members, instruction before as to what they are to see, and as many courtesies as possible from the plants visited, such as having as many guides as were extended to us, for instance, when we visited the Welsbach Co.'s plant. It is asking too much, particularly of small manufacturers, to take the time of their higher priced men, and we should make them feel that they have conferred upon us the supremest favor that they can do. Yesterday the office messenger of the steel works announced "The students are here." That was a very excellent term. Nothing would fit us better. We came there simply as students, and any man who goes on such visits with any other purpose is acting under false pretenses. I assure you that so far as Dr. Olsen and I have anything to do with it, the next meeting will be cared for about as well as our small efforts can make it.

Dr. GROSVENOR:

Is it understood that the next meeting will be held early in December, as it was the last time?

President MCKENNA:

I think there is no such provision, but we can set it down as a custom.

Secretary OLSEN:

It is merely a matter of precedent. A vote was passed at, I think, a meeting a year ago, that it be held within the first

fifteen days of December, and that the Summer meeting be held in the last fifteen days of June.

President McKenna:

If there are any suggestions that the members here would like to make regarding the conditions they would like to see observed at a meeting tending towards the comfort and instruction of the members, it would be well at any time to address them to the Secretary.

There is one other topic which arose out of the wish of the officers to make the Institute most useful at as early a date as finances will permit, in ways that no other agency can be useful to the members. It is the view of quite a number who have conferred upon the subject, that while a regular journal is not needed, and while our volume of Transactions is only needed to record the regular meetings and important papers there presented, the production of valuable literature in some form is, nevertheless, the duty of the Institute, and will make the treasury from which the members draw valuable information. It has also been suggested that the best results all told in the form of literature would be gained from what can only be a dream, but, nevertheless, it is as well to consider that dream—that ten years hence each member should have upon his library shelves a long, large group of volumes with adjustable bindings, having material in them, properly indexed according to the best of modern methods, covering all the features of mechanical aggregations that he can make use of, the results obtained with them in the best practice in the different classes of works using the different apparatus and materials, and monographs upon single individual subjects of chemical engineering. The suggestion of monographs was made by our honored first president, and has not yet been actively taken up.

Directions from this meeting would be timely. Some have said that compensation should be given to acknowledged authorities in the different branches to prepare monographs upon their branch. They could be given whatever would be decided upon —an interest in the copyright or in the sales outside the membership, or some other form of compensation immediate or prospective. Being gotten up on the loose leaf system frequent amendments would be easily possible, and would in the period

set for the dream—ten years' time—make a bulk of literature which could not possibly be obtained by any other means. It is not probable that any publisher could or would bring out such an amount of material, available only to a group of specialists.

It is perhaps possible that a publisher of an enterprising character might be willing to put up the capital to employ a group of abstractors, authors and clerks, and bring it out in a shorter period of time, and depend upon future sales all over the world for his profit; but still, some believe that the Institute will be doing a great work if it makes a start at the present time on some such proposition. You are all familiar with the unsatisfactory nature of the catalogues, particularly of chemical apparatus. Of course there is much in them that is valuable, but it is remarkable how things escape our hands when we want them. I drew up a scheme one day. I have never amended it, but have presented it to many of the officers of the Institute, and will offer it to a committee as presenting my views, which, if combined with the proposition for monographs, and carried out within a reasonable time, would, I believe, give this valuable literature that we want so frequently handy on our shelves.

With these discursive views on the subject, I think that quite a few minutes this evening could be properly devoted to a discussion of either that or the general topic—How can the Institute be most useful to its members? Those are the instructions the officers want.

Dr. GROSVENOR:

With a view to placing the matter in shape to discuss, would a motion be in order that the President appoint such a committee to take charge of the development of the scheme and if possible obtain an expression of opinion from the older and more important members of the Institute as to what can be done in that direction, or at least to present some data on which a judgment as to its ultimate feasibility could be based?

Motion seconded by Dr. Sadtler.

Mr. MEADE:

Is it your idea that the Secretary shall send out these various catalogues, or that the Secretary should prepare and send a list to manufacturers of things in which the members are interested, and that the manufacturers would be willing to send them out?

President McKenna:

The point is that they should be standard, uniform in size, and that this system of inserting and taking out material should be made practicable, otherwise it would not fit in with the scheme. The manufacturers might do most of the circulating and the Secretary might furnish the names.

Mr. Taylor:

I believe that a good lot of catalogues to-day is better than any work we have at the present time on chemical machinery, or even chemical engineering. The amount of information that can be obtained from the catalogues with respect to standard forms of drying machines, conveyors, and all sorts of machinery of that kind, is greater than can be obtained from any text-book that I have seen, and I believe that if the members collected a large library of catalogues it would be better than some of the books that are at the present time being sold as works of reference on chemical engineering.

Secretary Olsen:

I would like to ask for instructions. Some manufacturers write for list of members. Is it the desire of the Institute that I send them? I have not always done so in the past, for it was, of course, for the purpose of sending catalogues, and I did not think it desirable to have your mail loaded with that kind of literature. If you think it desirable I shall send them membership lists.

Dr. Grosvenor:

I think it was with precisely that point in view that our President spoke of the catalogue question. I think we all realize the enormous additional value of well-systematized catalogues, which in the ultimate development of our work must be considered. I believe it was his idea primarily that the catalogues would be printed, published, circulated, and with a little suggestion and co-operation, standardized by the manufacturer at his expense, and distributed to everybody. From this catalogue file would come organization, systematization, criticism, and ultimately the approval of a lot of machines of different types in the monographs of which he was speaking.

President McKenna:

Are there any suggestions on Dr. Sadtler's suggestion that we take steps to have important monographs produced under our auspices?

Secretary Olsen:

I would suggest that that might be referred to the Publication Committee rather than to a special committee

Dr. Grosvenor:

As an example, would it be desirable to have one of the most important papers presented at any meeting this year—the paper on the uses of a new material—put in the form of a monograph, not merely as it was presented, but with as much additional material as the author and other people who had used the material could furnish?

President McKenna

If the modern loose-leaf system was used, any improvements or new data, such as the discovery of new physical properties, can be immediately inserted without a new book or a new binding.

I will assume that this proposition then is referred by this body to the committee which I will appoint under the motion that was carried, and that that would be the way in which you would like to have the subject cared for. This committee will be asked to try and formulate, under the advice and with the suggestions of members to whom they might write, a scheme that would combine and co-ordinate information of value, particularly regarding processes and apparatuses for carrying on types of processes, so that it may be put in convenient form in the libraries of the members, and perhaps in such a form that the monographs could be sold entirely separate from the Transactions. If this is the view of the members as to how to handle this subject, I will put the motion. Dr. Grosvenor has seconded it I believe.

Carried unanimously.

President McKenna:

We now have a very pleasant duty to perform which I believe Dr. Grosvenor is going to take in hand.

Dr. GROSVENOR:

It is a very pleasant duty indeed to express the thanks of the Institute. I move that a vote of thanks be offered, and that the Secretary be requested to express such formally to the gentlemen and the companies who have extended courtesies to us here at Niagara Falls and Buffalo.

The companies to whom we are indebted for the courtesy of showing us through their plants are

Ontario Power Company,
Canadian Niagara Power Co.,
International Paper Co.,
Lackawanna Steel Co.,
The Larkin Co.,
Linde Liquid Air Co.,
H. W. Dopp Co.,
The Acheson Graphite Co.,
Wickwire Steel Co.,
Buffalo Foundry and Machine Co.

We are also indebted to the Larkin Company for serving a complimentary luncheon, and to Dr. Edward G. Acheson for furnishing cigars and wine at our dinner, and to Mr. A. Munro Grier, K.C., for giving us such a cordial welcome.

President MCKENNA:

I am sure that the Secretary will get the spirit of our gratitude and express it in the most heartfelt way. I am not going to be invidious when I say that Dr. Acheson deserves most thanks of us for his cordiality, his faithfulness, his extreme kindness, openheartedness, his open way in his own business, and above all, the attention to our comfort by his good son. I will put this motion of Dr. Grosvenor's with much pleasure.

Carried unanimously.

Mr. TAYLOR:

It may seem premature, and yet I would like to put a matter before us. The International Congress of Applied Science is to have its eighth meeting in America in 1912. We ought to grow pretty much in the interval, and I think we ought to have it in mind whether it might not be for the best interests of the Society that we have a department of chemical engineers in that congress. I simply throw it out as a suggestion for us to have in mind.

President MCKENNA:

Is any person here familiar with the way in which the departments you mention are let out?

Mr. TAYLOR:

There are some twelve or fourteen departments; for example, section ten is the electro-chemical department, there is another on analytical chemistry, another on photographic chemistry, etc. It is an organization of applied chemistry, and it seems to me that our organization should have a place in connection with that triannual gathering. It is in America this time after being abroad seven years. It was initiated at the World's Fair in Chicago in 1893, so that as a matter of fact its start was American.

Dr. SADTLER:

The whole thing is handled by an organizing committee operating from New York. The best plan would be to have this meeting pass a vote referring the matter to the Council, and ask the Council to put themselves in communication with the organizing committee. We cannot do anything by communicating as an Institute in a general way, but our Council can officially address the organizing committee.

President MCKENNA:

My personal view is that I would leave it to the courtesy of the organizing committee to address us. I think that our dignity would suffer a little if we sent a communication asking to be recognized.

Secretary OLSEN:

How long has this committee been organized in New York?

Dr. SADTLER:

Since last Summer. Steps were taken in London in 1909.

President MCKENNA:

I assume that Mr. Taylor's motion that the matter is important and be taken up by the Council for consideration, is the ruling attitude of this body. The Council is asked by this meeting to consider the representation of the Institute of Chemical Engineers at the International Congress of Applied Chemistry in America.

Announcement by Dr. Olsen with reference to further visits to plants open for inspection.

Meeting adjourned at 10.15 P.M.

THE EXCURSIONS

The Niagara Falls plant of the International Paper Co. was visited on Wednesday afternoon.

The first part of this mill visited was the ground-wood mill, where 8 grinders were in operation with a capacity of 65 tons per day.

In the sulphite mill, which is a 6-digester plant, with a capacity of 45 tons per day, the lime system for making acid is used. In this mill slacked Dolomitic lime is used as a base in the production of the bisulphites, while in most mills making this material large towers containing limestone are used for this purpose.

The paper mill contains 6 well-equipped paper machines, from 120 in. to 136 in. wide and has a capacity of about 120 tons of news and manila paper per day.

The plant of the Canadian Niagara Power Co. and the Ontario Power Co. were then visited.

The entire second day, Thursday, was devoted to visits to several important industries of Buffalo. A special car was chartered to take the members of the Institute and their guests from the hotel to the various works and return to the hotel. The attendance on these excursions was about 45.

At the plant of the Lackawanna Steel Company the large ore-handling apparatus was first inspected. The blast furnaces and Bessemer converters, and the very economical system of utilization of the blast-furnace gases proved very interesting. The hot gases were cooled by passing through the stoves used for heating the air blast, after which the dust was removed. The gases were then burned under boilers or utilized to drive gas engines of 2000 H.P. The open-hearth furnaces were also visited.

At the plant of the Larkin Company a complimentary luncheon was served to the visitors, after which a portion of the plant was inspected. The great variety of operations carried out and the excellent organization of the plant was remarked by all.

The last plant visited this day was that of the Linde Air Products Company. Here we found an admirable example of English courtesy and administrative ability, as well as a very well-designed plant, in which air is liquefied on a large scale. The nitrogen is allowed to evaporate, leaving oxygen of 96 to 99 per cent purity.

This is charged into cylinders and sold as compressed oxygen. About half of the oxygen of the air liquefied is obtained. The cold gases coming from the liquefied air are used to cool the compressed air before liquefaction. Much more time could, with profit and pleasure, have been spent at this plant. Every one left with reluctance, hoping to have another opportunity of visiting the plant.

On Friday afternoon the manufacture of graphite, at the plant of the Acheson Graphite Company, was inspected. The remarkable manner in which the element carbon has been modified to suit a great variety of purposes was very suggestive of what can possibly be done with other elements. Dr. Acheson himself conducted many of the members through the plant and afterward in his private laboratory demonstrated for them the properties of deflocculated graphite.

Sufficient time could not be found to visit the plants of the Buffalo Foundry & Machine Co., H. W. Dopp & Co., the Wickwire Steel Co., and J. P. Devine Co. for all of which permits had been obtained. As the plant of the Hooker Electro Chemical Co. had been partly destroyed by fire it could not be visited. It is evident, therefore, that another meeting could be held with profit in this delightful region.

THE DINNER

This pleasant function of each meeting was held at the Hotel Clifton Thursday evening. President McKenna acted as toastmaster in his usual tactful and charming manner. Mr. J. A. DeCew, of Montreal, Canada, welcomed the Institute to Canada.

Dr. Edward G. Acheson said that as he was a resident of Canada and a citizen of the United States he felt that he also desired to welcome the Institute. He expressed the opinion that in the name "Chemical Engineer" the Institute had selected a name implying a profession which studied matter and its transformation both on a small and large scale and so was more fundamental in scope than any other profession.

M. de Chatelain, professor of the Polytechnic Institute of Russia and president of the Electrolytic Section of the Imperial Technical Society of Russia, said that he found America very much in

advance of Russia in the application of electricity. He had come to America in order to study our methods of harnessing and utilizing water powers for the generation of electricity.

Past President Samuel P. Sadtler gave an outline of the growth of the Institute during the past six months.

Mr. A. Monroe Grier, K.C., of the Ontario Power Company, then made an eloquent address sparkling with wit and warm with humor on "The Future of Electricity," and many other interesting topics, including "The Ladies."

The following members and guests were present at the dinner:

Aylsworth, J. W.
Baker, J. T.
Camp, J. M.
Chatelain, M. de
Dannenbaum, H.
Dannenbaum, H., Jr.
De Cew, J. A.
Forbes, P. R.
Frerichs, F. W.
Frerichs, F. W., Jr.
Gano, William P.
Gibbs, A. E.
Gibbs, Miss
Gray, C. W.
Grosvenor, W. M.
Hahlweg, Geo. P.
Kotera, Fusaziro
Lihme, I. P.
Linder, Oscar
Lips, Carl, H
Mason, Howard
Mayer, Andrew, Jr.
McKenna, C. F.
Meade, R. K.
Miner, H. S.
Myers, Ralph E.
Olsen, J. C.
Randall, J. W. H.
Renaud, H. S.
Rosengarten, Geo. D.
Sadtler, Samuel P.
Shengle, John C.
Taylor, Miss Clara
Taylor, Miss Edith
Taylor, Edward R.
Taylor, Mrs. E. R.
Thomson, Stuart
Veillon, A. A. L.
Vorster, F., Jr.
Watson, John R.
Wiechmann, F. G.
Wright, R. G.
Zinkeisen, O. T.

AMENDMENTS TO THE CONSTITUTION

The amendment to the constitution instituting Junior Membership has been passed having received more than the necessary two-thirds majority vote of all members of the Institute and less than ten negative votes.

The amendment requiring the payment of the initiation fee immediately after Jan. 1, 1911, has been defeated. The original provision therefore remains that no initiation fee will be charged until the membership reaches 200.

With only one negative vote, the provision by which ex-presidents are made Members of the Council for two years has been passed.

THIRD ANNUAL MEETING

HELD AT HOTEL ASTOR, NEW YORK

December 7 to 10, 1910

MEETING called to order at 10 A.M., Wednesday, December 7.

The President in opening said that the New York members felt very highly complimented at the choice of New York City as a place of meeting, and when this selection was made at the Niagara Falls meeting they had then and there registered a vow to do everything in their power in the way of extending the utmost hospitality to make the present meeting a success. Although visitors might be critical of some things in New York, as, for instance, the old horse cars, there was not much that was really old in the city; buildings erected last year were torn down and replaced. They had no old men in New York, although they did not "Oslerize" them. But they were particularly proud of their young men, who had the courage of their convictions, and who stood for all that was best in our educational system and in our civic affairs. One of the best examples of this was a young man, lifted to a place of great honor—not because he was young; that was a bit of a handicap—but on account of character, honor and achievements; one whose civic pride was great, and whose civic courage was even greater. They could not have chosen a better type of all that is best in the young men of this city to welcome them, than the President of the Board of Aldermen, the Hon. John Purroy Mitchell.

The Honorable Mr. Mitchell congratulated the members on their choice of New York as a meeting place and said that it gave him great pleasure to extend to them a very cordial welcome to New York. He said that the great cities knew how to value men of their profession, and in particular to you who come here as chemists and as engineers this city has reason to hold out her hands

in very hearty welcome. As a manufacturing city New York has learned that no small measure of her prosperity and prestige is due to the contributions of her chemists, and as a city of magnificent public works she long ago learned that on the shoulders of her engineers rests the responsibility for these great factors in her progress and expansion. One of the first lessons that the government has learned is that for the conception, execution and realization of every important piece of work tending towards expansion and growth, she must run constantly and confidently for advice and guidance to the city's splendid corps of engineers. Those associated with public work have learned to understand also that a great part of the work of our engineers rests on the data gathered in the laboratory by men of the other profession to which you belong.

My experience has taught me how essential to the success of most classes of public work is the advice and knowledge of the chemist. Upon that knowledge, for instance, every bureau, department, head of department or engineer, must rely for specifications of materials, so that, for example, the asphalt may make good pavements, and the city may be protected against fraud. I recollect, for instance, the question of the specification for creosote oil to be used in impregnating wood pavement, and upon this controversy hung the question of monopoly and graft in city contracts. There are so many questions like this, of such infinite variety, and such great importance, that we long ago established a very extensive laboratory in the Department of Finance, and have but just now established a central testing laboratory for the use of all departments of the city. The City of New York knows how to value its chemists and engineers, and realizes the importance of both professions in the industrial and material progress of this city, and of the whole nation. For that reason we are very glad indeed to receive here in New York delegates to a convention, who, in their organization and personnel, so thoroughly represent these professions.

President McKenna, after thanking President Mitchell for the cordiality of his words, proceeded to the business of the meeting by appointing Mr. Hollick, Mr. Minor and Dr. Dannenbaum a committee to canvas the ballot for the election of officers.

He then said a few words about the work of the Institute in general during the past year.

The Institute has gained very much in prestige and position, and it has gained very much in membership. This gain is a total of 36, which is about twenty-five per cent. The publications of the Society have been regularly issued, and have met with an excellent reception, and cordial reviews and criticisms. Both volumes are now being sought for by all important libraries. The President was asked, ex-officio, to serve on the Committee of Organization of the Eighth International Congress of Applied Chemistry to be held here in 1912. This is an ex-officio position, and therefore reverts to the person holding office, this place on the Committee coming to succeeding Presidents, so that the Institute of Chemical Engineers has been very cordially invited into the council of the International Congress. He hoped that it will be properly represented at the Congress by the work of its members. He said it might be well for the Committee on Meetings to consider the question of holding the Summer meeting, or the annual meeting, in 1912, so that one of these meetings may be coincident, if possible, with that of the Congress.

Reading of Treasurer's report by Mr. Booth.

ANNUAL REPORT OF THE TREASURER

Dec. 10, 1909, to Dec. 3, 1910

Balance in bank	$401.55
Receipts	1957.25
Interest	13.93
Total	2372.73

Disbursements

Secretary	$262.83	
Treasurer	18.70	
Printing	606.33	
Stenographer	93.50	
Hotel Walton	105.85	
Speaker	14.80	
Returned Cheques	34.50	
Exchange	10.10	
		1146.61
Balance, Dec. 3, 1910		$1226.12

Respectfully submitted,
(Signed) Wm. M. Booth,
Treasurer.

Secretary Olsen:

The Secretary wished to make one statement which would take away the roseate hue of that part of the report which shows $1200 in the treasury. The bill for the printing of the second volume of the Transactions had not yet been paid. The Secretary desired to inquire into the items. The bill for that volume would just about use up the balance, and still leave a few dollars to the good, which was quite satisfactory.

The Secretary then read the report of the Membership Committee.

REPORT OF MEMBERSHIP COMMITTEE

The Membership Committee had held three meetings since the semi-annual meeting in the Summer, and had sent out three ballots for members, which all members have received and voted upon; had canvassed these ballots, and had been pleased to note that all candidates who had been recommended by the committee had been elected. About 75–80 ballots are cast at each vote out of a membership of something over 130, indicating that something like two-thirds of our members take the interest to mark and return these ballots. The Membership Committee has also worked on the certificate of membership to be issued to all members, and after great care has finally adopted a form which is at present in the hands of the engraver, and inside of a few weeks the printed certificate will be ready. It will be printed in three colors—black for the main type, while the badge will be reproduced in gold and red, and the printer has guaranteed a permanent color similar to the red in the button. This matter cannot be hurried because it is desired to have the incorporation brought about first, and have the seal prepared with the incorporation statement on it. Otherwise this certificate would have been ready a little earlier. The committee has done no further work on the matter of preparing a list of men who could probably be invited to become members, and undertaking some campaign to induce them to join. There seems to be a difference of opinion in the Institute as to the advisability of doing this.

A. C. Langmuir, *Chairman.*

REPORT OF SECRETARY

THE Secretary had not prepared a formal report of his office. The Secretary's work consists very largely in getting recommendations for candidates for the Membership Committee, and preparing material for action by this committee. There is one difficulty which arises in this connection, in that quite frequently candidates will send in applications with only one or two references, and members ought to be rather careful when their friends send in applications. In all cases the five names are used, and if seven or eight are submitted, all of them are used, so that it is quite necessary that five names appear on the application, so that full information can be obtained. Other applications will come in with no statement with reference to education. The committee cannot act on such applications.

The general correspondence of the office is, of course, fairly large, with the votes and circular matter to members. The publications require the largest time from the office.

Two bulletins have been issued during the year, and an opinion is desired as to whether these bulletins are desirable, and as to whether they should be continued.

The Transactions require a great deal of labor. The papers have been sent to all members of the Publication Committee during the past year, and all members of the committee have passed upon all papers. Difficulty arises because the papers are not promptly sent to the Secretary. In some cases we have waited six or eight weeks, which has greatly delayed publication. Members are urged to send in papers read at this meeting, so that we can get them to the committee and have them passed upon. There may have been some little dissatisfaction at the lateness of the issue of our Transactions. The Secretary would take some blame for that, as his other duties sometimes delays the necessary attention to the papers. It requires constant attention to get the printer to stick to his job, and do all the necessary proof-reading, and if it were possible to give a great deal more time to the printer it might be possible to get them out perhaps six weeks earlier.

J. C. OLSEN, *Secretary.*

Mr. Booth said:

He had listened to the report of the Secretary, and could say that he very much appreciated the fact that the Secretary worked for the publication of the Proceedings; that in his estimation the proofs were very carefully read, and as far as possible no mistakes appeared in the volume. Many chemical engineers with whom he was acquainted desired to buy volumes for personal use, and he believed it to be very important that the Committee on Papers, and the Secretary should act cautiously and very carefully, to see that nothing creeps into these volumes that will not be to the best interests of the Society. In other words, the volumes are now considered of high authority in connection with the subjects that are treated, and every effort must be made to maintain this dignified position. He wished to say that everyone appreciated what the Secretary had done for this Society in carefully proof-reading the papers, and returning them again and again until everything was correct. Have you thought of a man you can take these volumes to and say, "Are the statements made in this volume correct?" He did not know where such a man could be found. We have to take the papers to specialists, and say, "Look this over, criticise it, and improve it if you can." Sooner or later the Transactions should become the final authority, and contain the latest thing said in connection with certain industries.

Dr. Andrews said:

The Secretary in his report had asked for an expression of opinion with regard to the bulletins, and whether it was desirable to continue their publication. He stated that speaking for himself, he would be sorry to see the bulletins discontinued, more particularly as those members who are somewhat isolated from the majority are considerably dependent upon them for getting in touch with the affairs of the Institute, and he hoped that the publication would be continued.

He suggested the publication in advance of the Transactions of separate reprints of the individual papers, to be sent to all members, as is done in some engineering societies. That plan has advantages so great as to justify even considerable additional expense. In the first place, it is of very great advantage to the member whose paper is to appear. It frequently happens that

in one of our papers matters are touched upon which lie somewhat aside from the special field of investigation—matters in which the author is not so entirely an expert. Errors may in that way creep in, which, if the paper is published in the form of an advance sheet, will be tolerably sure to be corrected by other members bringing them to his attention before the final publication of the paper takes place. In other words, we have in that way a protection to the individual member, and to the Society as a whole. I would like to know whether other members share my views in this direction, and I should like to know from the Secretary whether he can give us an approximate estimate of the additional cost of publication of advance sheets.

The Secretary stated that the cost would not be serious, because the matter could be kept set up. There would be merely the additional press work, and the binding of the little pamphlets, which is not very great.

Mr. Booth:

I make a motion that papers to be presented at any meeting be printed in advance of the meeting and transmitted to the members.

Motion seconded by Mr. Grosvenor.

Mr. Booth:

The American Waterworks Association does that, and it is very valuable.

President McKenna:

This means that papers about to be presented to any meeting be printed and circulated before the meeting, and has no reference to appearance in bulletins or anywhere else.

One great advantage has been overlooked in the discussion. It would make it possible to have a full discussion of a paper after it had been presented to the meeting. If a member has never heard or seen a paper beforehand, he is very much at a disadvantage when he gets up to discuss it. If he had a chance to look over it, he would come prepared for the discussion and if he were unable to come could send in a written discussion. Everybody would be prepared to enter into the discussion—that seems the greatest advantage.

Mr. Booth:

If there are errors in any paper, they will be very liable to be discussed at the meeting at which it is read, and brought out. That seems to me the most important place to discuss the paper fully. We want to have the opportunity to work out the mathematical formulas and to read the paper at home. In a way the full discussions would be very valuable to the final proceedings.

Mr. Renaud:

I think that, outside of the question of expense, the method of printing the papers previous to the meetings would be the most advantageous way to discourage attendance at the meetings. The man living a little distance away would read the paper and would not come. The item of expense too is a serious one, and we are running pretty close to the high water line with respect to expense at present.

Dr. Andrews:

It appears to me that the question as to the desirability of publication of a paper in advance of the meeting depends to a very considerable degree upon the character of the paper. In the case of some papers it seems to me unquestionably of advantage; on the other hand, the objections made by the last speaker are very valid. At the same time, whether the papers should be published in advance of a meeting undoubtedly depends primarily upon the man who reads the paper. In many cases the Secretary would find it very difficult to secure the manuscript in advance of a meeting. Some members would prefer to have their papers come fresh before the meeting, rather than deliver a paper already read in type by all the other members. Since, therefore, it would depend upon the individual reading the paper whether it can be published in advance or not, I would prefer a form of resolution which I have written here, and which I would propose as a substitute to the resolution before the Institute; a form which leaves it open whether publication shall take place before the meeting or not, and simply provides that it shall take place in advance of the publication in the Transactions:

Resolved, that the Secretary be authorized to distribute to the members advance copies of the papers read at any meeting in advance of publication in the Transactions.

Accepted by Mr. Booth.

President McKenna put Mr. Booth's motion in the form read by Dr. Andrews before the meeting, and the motion was carried (seven for, five against).

Dr. Andrews:

I now move my motion as a new motion, instead of as a substitute. We have now provided for the reading of certain papers before the meeting, and I now ask for a vote to be taken for the advance printing of papers before the publication of the Transactions. This would only apply to those which had not yet appeared.

Dr. Grosvenor:

That means advance prints, possibly in proof or galley form just prior to publication in the Transactions, for the purpose of accuracy and correction chiefly?

Yes.

I second the motion.

Mr. Adamson:

Does that mean that a reprint is to be sent to every member, or a galley proof sent to every author?

President McKenna:

Those authors who sent their papers in previously, and had them printed in advance, according to Mr. Booth's system, would not have these papers printed again until the Transactions are published. This resolution would provide that papers read at any meeting be printed in advance of the publication of the Transactions. Those which had been printed under the previous ruling would not be printed again, but those which had been sent in in the interim between that meeting and the appearance of the transactions would be printed.

Secretary Olsen:

This resolution merely authorizes the Secretary to do it. It does not say he shall do so, but merely says that in certain cases he may do it, if it is considered feasible and desirable.

Dr. Andrews:

Yes, that was the way in which it was intended.

Motion carried.

Mr. Booth:

The report of the Medal Committee was presented and discussion deferred until Friday.

President McKenna:

The report of the Committee on Publications will be considered as having been rendered, inasmuch as Dr. Andrews, the second member of the Committee, has spoken on the subject, and the Secretary, who is really a member of it, has already reported fully.

Mr. Renaud:

The report of the Finance Committee is not ready.

Mr. Baker:

I have a resolution to offer in connection with the incorporation proposition. (Reads the following resolution.)

RESOLUTION ON INCORPORATION

On the 7th day of December, 1910, a regularly called meeting of the unincorporated association known as the American Institute of Chemical Engineers was held at the Hotel Astor, in the Borough of Manhattan, City, County and State of New York. Thirty (30) days before such meeting, notice of the intention to incorporate said association was given by mail to each member thereof whose residence or post-office is known. And at said meeting the following resolutions were offered, seconded and duly adopted by the unanimous vote of all the members present, to wit:

" Resolved that it is the sense of the members of the American Institute of Chemical Engineers, in general meeting assembled, that it is desirable and necessary for the well being of said association and its members and for the furtherance of the objects for which the same has been formed, that said association incorporate under the Membership Corporation Law of the State of New York.

And further Resolved, that the name of said corporation as hereby adopted by this meeting shall be American Institute of Chemical Engineers.

And further Resolved that said incorporators shall be named in the Certificate of Incorporation as directors of such corporation until its first annual meeting, and that such directors and their

successors in office shall be, and they hereby are, authorized to enact and adopt a Constitution and By-Laws for the government of said corporation."

Motion seconded by Mr. Adamson.

President McKenna:

This is a matter for very serious consideration, gentlemen. Mr. Renaud has been working as legal counsel, for which work he is eminently fitted, on this proposition, and has done all the actual work of securing the incorporation of the Institute; he has the papers all ready; he is getting the signatures here of the incorporators, and is going to court to-day if this body votes favorably to present them, so that on Friday he can announce that the Institute is fully incorporated, and consequently we do not want to make a mistake. We do not want it to be delayed, if it should not be delayed, and do not want it to go forward with a title not as desirable as another. I therefore ask you to give your best thought to this and decide the question quickly. We have now before us the proposition to elide the word " American," not from unpatriotic motives, but from motives which should be seriously considered. Are there any gentlemen here with strong views on the subject of whether any damage may come to this Institute in the future, any sympathetic, moral or æsthetic disadvantage, from the continued use of the word " American?"

Secretary Olsen:

I am in favor of using it, Mr. President. We are an American institution, no matter what our name is.

Dr. Weichmann:

I think it very desirable to retain the word " American," and rather a distinction than otherwise that Americans founded the first chemical engineering institute.

President McKenna:

Shall the resolution introduced by Mr. Baker, and seconded, be amended by eliding the word " American " from the title of this Institute?

The noes have it, and the elision will not take place.

We should now vote on the resolution for incorporation as introduced by Mr. Baker.

Mr. RENAUD:

I would call the attention of the members to the fact that, in order to incorporate legally, the motion must be passed unanimously. I do not know that any members have any objection to incorporation and have prepared no brief in favor of it. I am willing, however, to restate a few of the conditions. In the first place, incorporation of the Institute gives it a legal standing whereby contracts can be made and enforced in the name of the Institute. Now this cannot be done. Consequently it limits the liability of its officers and members. As you are all no doubt aware, at present the officers and members are individually and collectively liable for any of the debts of the Institute. As an incorporated body this would not be true. The only liability would be the property belonging to the Institute. Our Secretary knows that it would be of advantage to be recognized by the United States Government. Copyright laws simply recognize individuals and incorporated bodies. Now we have to copyright in the name of the Secretary. If we go to the Government now and try to get a cheap lot of envelopes, we cannot do it. The American Chemical Society at first was not incorporated, and after a year or two of existence tried to hire a hall in New York City, and found that they could not enter into a legal lease, nor even hire a hall. Another point brought out some time ago, was as to whether it would not be advisable to have a federal incorporation. There is no such thing. Incorporation is a matter of State rights, and is done by the States individually. State incorporation now is just the same as a federal one. It carries weight throughout the country, and a New York State corporation can do business in all States.

The motion put by Mr. Baker was carried unanimously.

Mr. BOOTH:

There is just one point I should like to make. The friends who have bought these volumes of the Transactions tell me that they do not care for the proceedings of the Society in them, and it is my opinion that they should be eliminated.

President MCKENNA:

Would you not leave it to the Committee on Publications to make them as brief as possible?

Mr. BOOTH:

I just wanted to call the attention of the Society to the fact.

The report of the Committee on Chemical Engineering Education was then read by Dr. F. W. Frerichs.

Dr. Fred W. Atkinson, President of the Polytechnic Institute of Brooklyn, then read a paper on the Development of the Chemist as an Engineer.

Prof. M. C. Whitaker read a paper on the Training of Chemical Engineers which meets the Requirements of Manufacturers.

A. H. Sabin, of the National Lead Co., read a paper on Teaching Industrial Chemistry.

Meeting adjourned at 12:30 A.M.

Wednesday Evening Session.

Meeting called to order at 8 o'clock by President McKenna in the chair.

President McKenna said that:

When Professor Bogert invited the Institute to hold a meeting at Columbia he did something which was particularly gratifying to the officers and members of the Institute, and something which was also characteristic of himself, in recognizing that men of affairs would be glad to return to the academic precincts. It is uplifting and consoling sometimes to return to halls of learning, to review the subjects and remember the time when we were devoted to the pursuit of the knowledge of truth and the working of nature's laws, to ponder over the high thinking which we are accustomed to associate with these places, and all of those things which we think of as the antithesis of our every day, hurly burly life. Meeting here serves to recall to Columbia men a great many ambitions, hopes and dreams, and recollections and memories of our dearly beloved instructors, Chandler, Van Amringe and Trowbridge. The profession of chemical engineering in America owes a debt to Professor Chandler, which it fully recognizes, and he, in his retirement, must feel happy in the recollections of his recent jubilee, and of the fact that when he did retire, there was not one word but of respect for him, and of the evidence of really deep affection for him. The men who succeed him in this department are the pick of his own pupils. The President regretted very much that Professor Bogert himself, due to a slight illness, was not able to be present. They should be very glad,

however, to hear from their dear friend and fellow member, Professor Whitaker.

Professor WHITAKER:

Regretted very much the inability of Professor Bogert to be present, inasmuch as he was sure he had something to say, and furthermore, inasmuch as he himself had already monopolized a certain portion of their time to-day, he did not feel that it was his place now to add anything more. He had the honor of voicing the sentiments of the department and the university, by extending a welcome to the Institute, and inviting them to make themselves at home in its laboratories, not only then, but in the future. We have a handsome equipment here, from an architectural standpoint at least, and it is being utilized to its limit. Something will have to be done before long to increase the efficiency or effectiveness of the "filtration process," or else to take care of a larger body of students. It has been suggested several times to-day that possibly higher standards might accomplish a great deal towards making better chemical engineers, and it is my general idea that this is true. We hope to accomplish something towards reducing the tremendous output, and improving the quality. We need the assistance of chemical engineers in telling us exactly what to do, and how to do it. We do not want to stand on any pinnacle, and say that we cannot be advised. We are here shouting for advice. I am sure that Professor Bogert is very sorry that he cannot be here, and that what he had to say would have been someting of interest, and would have contained valuable suggestions along lines of chemical training.

President McKenna replied that it was always an honor to be in a position such as he finds himself to-night, when something is expected in the way of a professional report before laying down an office, and one is fortunate indeed if he can find material for a thesis which interests the hearers.

Dr. Chas. F. McKenna, as the retiring President, then delivered an address on the Evolution of Portland Cement Processes.

Richard K. Meade then read a paper on the Manufacture of Hydrated Lime.

Announcement of Thursday's programme was made by Dr. Olsen, and the meeting adjourned at 10:30 P.M.

Friday Morning Session

Meeting called to order by President McKenna at 10 A.M.

President McKenna:

Gentlemen, we resume the sessions of our Convention, and the incoming officers will now take charge of the meeting.

Announces result of ballot for officers. (List of officers elected and the Committees appointed by President Frerichs for 1911 will be found on p. 77.)

I bespeak for Dr. Frerichs the same hearty and cordial support which you have given me in my administration.

President Frerichs:

Gentlemen, I thank you in the name of the newly elected officers, and for myself, for the honor which you have conferred upon me. It is a compliment for anybody to be elected an officer, and even to be nominated for one of the officers in a society where there are so very many able members as there are in this Institute. So far as I am concerned, I have to state that my ability to conduct an organization like this is limited, but, if you will promise to help me, I will consider myself as first among equals, and will try to conduct the business of this organization to the best of my ability.

The Committee on Meetings was to report this morning. Is one of the gentlemen on that Committee present?

Secretary Olsen:

Mr. President: The one matter which this Committee needs to report upon, is the place for holding the next meeting, and possibly the annual meeting—that is also usually discussed. The Committee on Meetings was instructed at one of our sessions to consider the question of a place for the succeeding meeting and report. There has been considerable discussion of this matter, and Chicago has been mentioned as a suitable place for holding our summer meeting. Chicago has the advantage that it is situated on the lake, where we could get the advantage of cool summer breezes. There are one or two hotels on the lake front—modern and suitable for headquarters. There are a number of excellent plants in the vicinity. Gary is on the south side. On the west side there is the new plant of the Corn Products Refining

Co., built in four units, each unit designed to handle 15,000 bushels of corn per day, which in actual operation will probably be 20,000 bushels. There are the stock yards and packing industries, and other important chemical industries. The Institute has desired to hold a meeting in the west. We have considered St. Louis, but the furthest west we have gone is Pittsburg. We have four members in Chicago and one in Hegewisch. Altogether it seems a desirable place to hold a summer meeting. St. Louis is not so desirable on account of the high temperatures which frequently afflict the inhabitants during the summer months. The other place which has been considered for our coming meeting is Boston. We have not many members in and around Boston. It is an excellent center of many industries, and perhaps the question is whether we wish to hold our summer meeting in Chicago, and the next annual meeting in Boston, or whether we shall reverse the order. I think myself we would have a larger attendance at an annual meeting held in Boston, and do not think we should have a very large attendance at a meeting held in Chicago. The annual meeting is the most important, and we should insure a large attendance there. Boston is somewhat cooler than Chicago, although a Chicago blizzard is someting terrific; once stuck in a blizzard you cannot get anywhere. That is the Committee's report. They recommend these two places as possibilities for our next meeting.

Mr. RENAUD:

There was some talk six or eight months ago about having a summer meeting in the neighborhood of Atlantic City.

Mr. MCKENNA:

Atlantic City is removed from any points of interest.

Dr. WEICHMANN:

It is a general proposition that the smaller city has advantages over a larger city. It has always seemed to me that in the smaller cities like Detroit, Cleveland, or Milwaukee, we would be better accommodated than in the large cities, and, as the industries in these smaller places are more centralized there would be less time wasted in getting back and forth. A city like Milwaukee, where we could study the tanning and enamelling industries, the Allis-Chalmers plant and the breweries, would give us

all we could handle in the way of excursions, and a meeting there would prove a delightful experience in the entertainment extended. The Michigan Gas Association has introduced a novel scheme by holding their sessions on a boat. We could not visit chemical industries on a boat, but we could hold meetings there, and it would probably insure a good attendance the lack of which Dr. McKenna was objecting to this morning. We could have the stewards get them out. This, at least, would be a decided advantage. We could charter a boat, and go as far as we wanted to. We might wind up in Duluth, where we should find many interesting things. All these schemes are simply suggested as the experience of other organizations. The general scheme that our meetings should be held in the north in the summer, and as far south as possible in the winter is a valuable one, that we ought to stick to.

President FRERICHS:

It is quite a new proposition to have a meeting on a boat, and it might be considered.

Dr. SADTLER:

I was talking yesterday with Dr. Olsen, and I did not then think that Chicago would be a very advantageous place, but the longer I consider the matter the more inclined I am to think that it would be. Chicago University is in the neighborhood, and the Beach Hotel on the water front would be away from the bedlam of the city, and we could keep our members together. The excursions in the vicinity of Chicago would be superior to those in the vicinity of smaller cities; what with the electrical industries there, the stock yards, Gary, and the new Corn Products plant, there would be a great deal of considerable interest. I had thought of Detroit too, but I understand that it would be very difficult to get access to some of the chemical industries in that neighborhood. Unless we knew that we could get in, there would be very little use in meeting in Detroit. I do not think we are strong enough to take up the boat-excursion idea. In Chicago we would be doing valuable missionary work, and I believe we might interest ten or a dozen chemical people, who might come into the Institute and add strength to it. I am rather in favor of Chicago as the place for the next meeting.

Dr. McKENNA:

Milwaukee would be an excellent meeting place, but I have come back to the belief that Chicago offers most inducements to the Institute at the present period of her history. The steel works and the new town of Gary will be extraordinarily interesting to those of us who have not been there. With the variety of technical operations in the town, there will be enough to keep us occupied, and with the new plant of the Corn Products Refining Company to visit, and the other argument of perfecting our organization amongst the strong men in the middle part of our continent, Chicago seems to offer the most advantages, as excellent a suggestion as Milwaukee is.

President FRERICHS:

What is the pleasure of the Institute with regard to this question. Shall we decide it now, or leave it to the Committee?

Mr. McKENNA:

I think we should get the sense of the meeting, and report it to the Committee on Meetings.

President FRERICHS:

I understand it to be the sense of this meeting that the next semi-annual meeting shall be held in Chicago, and that it be left in the hands of the Committee.

Henry Stanley Renaud then read a paper on the Manufacture of Lignite Briquettes.

David Wesson read a paper on Bleaching Oils with Fuller's Earth.

Jerome Alexander read a paper on the Fitzgibbon Boiler.

President FRERICHS:

I now wish to make a few announcements. A meeting of the Council was held on Wednesday, and two vacancies amongst the officers were filled. Dr. Edward G. Acheson of Niagara Falls was elected Vice-President two years ago, and would have been First Vice-President for the coming year, but, as the members saw fit to make Dr. Acheson a director, the Council assumed that the Institute desired that he should fill this latter office and not that of Vice-President. It may possibly be to the point, and I may not be trespassing on any confidence by saying that Dr. Acheson has expressed very strongly his desire not to be elected

to the Presidency, so everything seemed to fit together. The office of Second Vice-President therefore being considered vacant, Mr. George P. Adamson, who received almost as many votes for Vice-President as Dr. Baekeland, was elected by the Council to serve for the coming year.

Dr. S. P. Sadtler was elected director a year ago. The Institute amended the constitution so that ex-presidents were members of the Council for two years succeeding termination of their office. By this action Dr. Sadtler's position as director would be considered vacant, and Mr. J. T. Baker, who received the fourth highest number of votes for director, was nominated by the Council, and elected to fill this position. It is desired to have a short meeting of the Council immediately after the adjournment of this meeting.

The President then called on Mr. Booth for the report of the Committee on Medal.

REPORT OF COMMITTEE ON MEDAL

The American Institute of Chemical Engineers, incorporated under the laws of New York State, with an office in New York City, has voted to award a gold medal to the author of the best original contribution to the literature of applied chemistry, such contribution to be presented only to the American Institute of Chemical Engineers with provisions as follows:

1. Members and non-members may compete.

2. The paper must be mailed by registered post to the Secretary of the Institute, John C. Olsen, Polytechnic Institute, Brooklyn, N. Y., at least sixty days prior to the semi-annual meeting in June, 1911.

3. The papers will be examined by the Committee on Publications, of which William P. Mason, Rensselaer Polytechnic Institute, Troy, N. Y., is chairman.

4. The first announcement of the award shall be made by the President of the Institute at the semi-annual banquet when the honor will be conferred.

5. If, in the judgment of the committee, no paper presented is worthy of the proposed honor, the award will not be made.

The contribution must be submitted in typewritten form in duplicate.

A Medal Committee has been chosen to solicit funds for this purpose. The members of the committee are:

Samuel P. Sadtler, 39 So. 10th., Philadelphia, Pa.; Joseph W. Richardson, Lehigh University, So. Bethlehem, Pa.; Andrew D. Robertson, 2 North 9th St., Richmond, Va.; Wm. M. Booth, chairman, 710 Dillaye Bldg., Syracuse, N. Y.

It is proposed to raise by subscription twelve hundred and fifty dollars ($1250.00). This is to be invested for the Institute and shall be known as the "Medal Fund," the interest of which is to be used for the award. Any person or corporation may contribute. Any subject for investigation and report may be suggested. However, all moneys received will become a part of the general fund set aside for this purpose.

You are cordially invited to contribute. The members of the committee feel that some very valuable papers will be presented and that one of the main aims of the Institute will be accomplished—"To publish and distribute such papers as shall add to classified knowledge in chemical engineering and shall increase industrial activity."

WM. M. BOOTH,
Chairman.

MR. BOOTH:

It has also been suggested to me that the Committee on Publications shall look over and examine the papers in competition for the medal, so that another committee will not have to be appointed to examine these papers, and I would like to make a motion that the Committee on Publications be empowered to examine all papers that can enter into competition for the proposed medal of the American Institute of Chemical Engineers to be awarded next June.

MEMBER:

I thought it was to be awarded at the annual meeting.

MR. BOOTH:

The report was so made, but it was my understanding that the award was to be made at this meeting when this report was made.

DR. MCKENNA:

That matter should be deferred to the June meeting because some of the papers were not read.

Secretary OLSEN:

We can award in June for the papers of the present year.

Dr. MCKENNA:

Do I understand that the mere presentation of a paper to the Secretary and its passage by the members of the Publication Committee and of the Medal Committee is sufficient, without awaiting its presentation at our annual or semi-annual meeting? I think this was the meaning of the members during the discussion. If it was formally recognized by the Committee it was sufficient.

Secretary OLSEN:

The intention was that it should be presented to the Secretary before a meeting, and should be passed upon by the committee, and, undoubtedly, the idea was that it should be read at the following meeting. The provision was that if some member had a paper for this meeting he should present it sixty days in advance, so that we had sixty days in which to pass upon the papers and award the medal before the paper was read.

MEMBER:

Is it stipulated that it should not be presented elsewhere first?

Mr. BOOTH:

An original contribution.

Dr. MCKENNA:

I think we should add the words "the first announcement of which is made at the Institute."

Mr. BOOTH:

I do not see how you can get ahead of this word "only."

Mr. ALEXANDER:

Could a paper be presented and get the medal without having been read before the Society?

Mr. BELDEN:

It seems to me that this is a matter of a great deal of importance, and that we ought to wait until we have disseminated the information with regard to this medal. I move that the award be made at the next annual meeting. It will take something like six weeks longer to get this information in printed form and before the public, which reduces the six months considerably. It seems

to me that if we are going to have a medal, we do not want it held cheaply. By delaying the presentation of the medal to the next annual meeting there would be ten months in which to consider it.

Dr. McKENNA:

I believe that should be a separate motion, which would have to follow the one before us at present.

MEMBER:

Second the motion.

Secretary OLSEN:

In our August bulletin, which has been sent to all members, this matter was clearly stated. It was decided to present the medal during the current year. This was clearly understood at the Niagara Falls meeting.

Dr. McKENNA:

The subject was discussed and I took a vote, after a great many different propositions has been discussed, and the committee had the sense of that meeting, and has embodied it in the wording of the present report.

Mr. BELDEN:

I still insist that this is a matter of importance. If we rush it through as quickly as this it will be held cheaply. If we get into that class we had better stop right now.

Secretary OLSEN:

I think we have had one or two fine papers, and I do not think it would be hasty. I think if we were to award for one of the papers already presented, everyone would agree that it would be satisfactory. One of the best ways to bring publicity to the matter would be to make the first award.

Mr. BELDEN:

Putting it off to the next annual meeting would not throw the competitors out.

President FRERICHS:

It would make this difference. If we postpone it to the next annual meeting papers presented in the year 1911 will be competing, while if we award it in June at the semi-annual meeting, the

papers will be considered which have been presented the previous years.

Mr. BELDEN:

It could be very easily amended to include all papers so far presented to the Institute.

Mr. BOOTH:

It is not of the slightest interest to me one way or the other, whether it is presented in June or December. If it is the sense of the members present to wait until the December meeting, the chairman of the committee will be very glad to wait. It will give very much more time to collect the money. We want the details discussed.

Dr. MCKENNA:

If it is the sense of the meeting that more protection should be thrown around the award it is worth while to discuss it.

Mr. ALEXANDER:

I would call attention to one point. It seems to me that any paper which is to be considered in a competition of this kind should have been read before the Institute, either by the author or the Secretary of the Institute.

Dr. MCKENNA:

That has been discussed before. It does not give opportunity for immediate and early presentation of a novel work when an invention is ready to be announced. A man might be ready to make an announcement, and no meeting coming, and a great many other societies might be imploring him for it. It was decided at Niagara Falls that under these circumstances it be recommended to the committee to lay down that mere presentation to the Secretary, and acceptance by the Committee on Publication would pave the way for the immediate announcement of the honor.

President FRERICHS:

The amendment means that the presentation of the medal be deferred until the annual meeting, and the competition be open to all papers presented to the Society sixty days before the date of the next annual meeting.

Amendment lost.

President FRERICHS:

We now come to the main question as to whether the award shall be made by the Committee on Publication.

Mr. RENAUD:

Is it understood that we are to consider only the papers coming up during the year, and not the previous papers? It might be that there were two able papers in one year, and one received the award. The one which did not receive the award might be more valuable than the papers presented afterwards. It seems fair that all papers presented previously ought to come up for consideration.

Mr. BOOTH:

This would very much complicate the situation.

Secretary OLSEN:

This motion before us is merely the question as to the committee which is to pass upon the papers. The reason why this task should be given to the Publication Committee is that the time consumed in examining the papers delays publication. This committee has to read them, anyhow, and has to decide on their merit. It will therefore facilitate matters very much to have this committee decide which is the best paper.

Motion carried.

Secretary OLSEN:

It seems to me that, as this is the first medal presented, it might be advisable that all papers presented up to date be considered, i.e., the papers in the first and second volumes of the Transactions and the papers presented during the present year, and also those presented to the Secretary within sixty days of the next meeting.

Mr. ALEXANDER:

I so move.

President FRERICHS:

The motion before us is that all papers which have heretofore been presented to the Society, including all papers presented to the Secretary within sixty days of the time of the award be considered in the competition.

Motion carried.

Meeting adjourned at 12:30 P.M.

JOINT MEETING OF THE AMERICAN CHEMICAL SOCIETY

AND THE

AMERICAN INSTITUTE OF CHEMICAL ENGINEERS

HELD AT THE CHEMISTS' CLUB, FRIDAY EVENING, DECEMBER 9.

MEETING was called to order by Professor Charles Baskerville, Chairman of the New York Section of the American Chemical Society, at 8:25.

The President and the Secretary of the Institute were called to the platform by Professor Baskerville.

Responding to a few words of welcome by Professor Baskerville, President Frerichs said:

It affords me great pleasure to attend on the occasion of our third annual meeting a joint session of the New York Section of the American Chemical Society and the American Institute of Chemical Engineers. I welcome this event, particularly since it would indicate that the two societies have become closely related and have become sister societies. Yours has a long and honorable career in science to point to. Ours is young and we shall have deserved well indeed of our science if we shall have made even a small part of the remarkable growth which your society has recorded.

Three years have been sufficient to prove to us that there is an extensive and specialized field for our endeavors and we know the rivalry, if there exists any, could only be of the most inspiring character, for we are really supplementing one another in our aims. That the two societies are really needed is perhaps more keenly felt in the west than here. Your section is amongst the foremost in doing great things for the science of chemistry in this country. The Nichols Medal has already brought fame to many a great chemist, and has brought equal credit to you for your

generosity in including all the great workers of the country in the field of contest for it.

Your chairmen have been distinguished, and not the least of the long line among men of honor in the profession is the young investigator and educator who graces the chair now. I have read with great interest an account of his address, delivered on October 7th, before this Section, in which he points out the fact that in many branches of your municipal government the advice of the chemist is missing. He strikes at the root of the failure of the chemist to occupy his proper place in the body politic by advocating a more general diffusion of chemical knowledge among the public—setting forth that no man or woman, whatever may be his or her calling, has a right to an academic degree unless the training involves one course in chemistry. In that course the relation of chemists to the commonwealth should be brought out and the presence of the chemist as an indispensable member of the muncipal government should be demonstrated. Such general diffusion of chemical knowledge would create a demand for chemists, and he points out that work in this direction is a worthy aim of your society. And truly, the American Chemical Society with its large membership, controlling the chemical departments in the high schools and colleges of the United States, would seem to be singularly fit to create a demand for chemists and chemical engineers, particularly in municipal government.

If the demand is created, the chemical engineer is needed, and to produce him is one of the aims of the American Institute of Chemical Engineers.

Like demand and supply, our societies supplement one another, and both organizations would seem to have their full right of existence, although in different spheres. Your aims cover the entire field of chemistry. You publish three valuable journals at frequent intervals and you count the best chemical scientists among your members. You have successfully established a forum before which purely chemical questions can be discussed and our great universities are lending you their assistance for your work. You have the great privilege of working in an ideal sphere where every truth developed is measured by the depth of argument, where the discovery of a new reaction is valued by the difficulties under which it was found.

But there is another field adjoining pure chemistry in which

chemical reactions are used for the production of goods. There the factor of dollars and cents enters into our calculation and the problem becomes one of handling labor and producing goods at low cost. In this field questions of chemistry become largely engineering problems, and in many cases to such an extent that the chemical problems underlying an industry often seem to be insignificant compared with the engineering work required for successful operation.

A striking example is furnished by the development of the ammonia soda industry. The chemical reaction underlying the process was known for many decades. Many chemists knew of it, but they could not put it into practical use, and there lived many engineers who did not know of the problem. It required a man with engineering and chemical knowledge like Solvay to put the process to work and to revolutionize an industry of a hundred years' standing.

This example represents the true field of the chemical engineer. This field is narrow compared with yours, but it is wide enough to support a profession which is represented by our Institute.

We all appreciate highly the aims and achievements of the American Chemical Society. Many of our members are with you also and we hope sincerely that sooner or later many of your members may also join our organization. By working together as sister societies we certainly could accomplish much for the advancement of American chemical industry.

The following papers were then read and discussed:

The Principles of Sewage Disposal, by Geo. C. Whipple.

Sewage Disposal in Europe, by Rudolph Hering.

Sewage Disposal in New York and Vicinity, by Dr. Geo. A. Soper.

Sanitary Conditions in their Relation to Water Supplies in the Vicinity of New York, by Nicholas S. Hill, Jr.

The Unsolved Problems of Sewage Disposal, by Prof. Chas. E. A. Winslow.

Meeting adjourned at 11:30 P.M.

EXCURSIONS

On Wednesday afternoon December 7, the Marx and Rawolle Glycerine Refinery, Brooklyn, N. Y., was visited. Members were especially interested in the inspection of the Wood's multiple effect stills which were in operation. The shellac bleachery was also inspected. At the close of the visit refreshments were served by the company.

On Thursday morning, December 8, members and their guests assembled at Pier 4, North River, and were conveyed by a steam lighter of the Standard Oil Company to the Bergenpoint sulphuric acid plant of this company. The visitors were divided into three squads and were shown every detail of the plant by the Superintendent, Mr. B. H. Baldwin, and his assistants.

The party was then conveyed by the boat to New Brighton, Staten Island, where luncheon was served at Hugot's restaurant. The Hon. George Cromwell, President of the Borough of Richmond, addressed the company and Mr. Heenan explained the operation of refuse destructors. During the afternoon the plant installed by the Heenan Destructor Company for the Borough of Richmond, was inspected. The very successful operation of this destructor of ashes, garbage, etc., was admired by all the visitors.

On Friday afternoon, December 9, the Candle House and Grease Works of the Pratt Works of the Standard Oil Company at Blissville, L. I., was visited and found both interesting and instructive.

On Saturday, December 10, the chemical museum and laboratories of Columbia University, as well as the chemical buildings and laboratories of the College of the City of New York were visited.

DINNERS

The dinner was held at Hotel Astor, on Thursday evening, December 8, About forty-five members and their guests were seated at the tables.

Dr. McKenna acted as toast-master in his usual charming manner. Professor Baskerville extended greetings from the American Chemical Society. Mr. E. A. Sperry gave a number of amusing incidents in connection with the early history of the Society of Electrical Engineers and predicted as great a growth for the Institute of Chemical Engineers as he had witnessed in the case of the Electrical Society. Mr. J. A. DeCew responded to the toast: The Canadian members. Dr. Samuel P. Sadtler, as our first President, spoke of the first year's work of the Institute, and our newly elected President, Dr. F. W. Frerichs, spoke of the work for the coming year. Mr. Geo. C. Whipple and Professor Wm. P. Mason, related amusing incidents in connection with their work as sanitary water experts. Mr. Rudolph Hering spoke of the early work in this field.

On Saturday evening, December 10, Dr. Jokichi Takamine entertained at a Japanese dinner given at the Nippon Club, New York City, the officers of the Institute. The Japanese Consul General of New York, Mr. K. Midzano, was also present and assisted the genial host in entertaining his guests in the cordial and charming manner characteristic of the Japanese.

CONSTITUTION

ARTICLE I.

NAME.

This organization shall be termed,

AMERICAN INSTITUTE OF CHEMICAL ENGINEERS.

ARTICLE II.

OBJECTS.

The objects of this organization shall be:

To advance the cause of applied chemical science.

To give the profession of Chemical Engineers such standing before the community as will justify its recognition by Municipal, State, and National authorities in public works.

To raise the professional standard among Chemical Engineers, discouraging and prohibiting unprofessional conduct.

To coöperate with educational institutions for the improvement of the education of the men who are to enter this profession.

To encourage original work in chemical technology.

To promote pleasant acquaintance and social and professional intercourse among its members.

To publish and distribute such papers as shall add to classified knowledge in chemical engineering and shall increase industrial activity.

ARTICLE III

MEMBERSHIP

SECTION 1. (*Qualifications for Membership.*) Membership shall consist of two grades: Active and Junior.

ACTIVE MEMBERSHIP shall require the following preparation and training:

All candidates must be not less than 30 years of age and must be proficient in chemistry and in some branch of engineering as applied to chemical problems, and must at the time of election be engaged actively in work involving the application of chemical principles to the arts. All candidates for admission to this Institute are expected to have *expert knowledge of at least one branch of applied chemistry.* and must fulfill one of the following requirements:

1. Candidates who hold no degree from an approved university or technical school must have had ten years' experience in chemical technology; five being in responsible charge of operations requiring the elaboration of raw materials, the design of machinery involving chemical processes, or the application of chemistry to industry.

2. Candidates who hold the degree of A. B. (Bachelor of Arts) from an approved university or technical school offering a four-year course must have had at least eight years of practical experience as outlined under No. 1.

3. Candidates who hold the degree of Ch. E. (Chemical Engineer), B. S. (Bachelor of Science), in Chemistry or Chemical Engineering, or E. E. (Electrical Engineer), C. E. (Civil Engineer), or M. E. (Mechanical Engineer), or equivalent degrees from an approved university or technical school offering at least a four-year course, must have had at least five years' practical experience as outlined under No. 1.

4. For candidates who in addition hold the degree of Ph. D. (Doctor of Philosophy) or Sc. D. (Doctor of Science) in Chemistry, the number of years required to earn the higher degree may be deducted from the number of years of experience required.

JUNIOR MEMBERSHIP shall require the following preparation and training:

All candidates must be not less than 23 years of age and must be engaged, at the time of election, in some branch of applied chemistry and must fulfill one of the following requirements:

1. Hold the degree of Ch.E. (Chemical Engineer), B.S. (Bachelor of Science) in Chemistry or Chemical Engineering, E.E. (Electrical Engineer), C.E. (Civil Engineer), M.E. (Mechanical Engineer), or equivalent degree from an approved university or technical school offering at least a four years' course.

2. Have had five years' experience in Applied Chemistry.

Junior Members shall have all privileges of the Institute excepting those of voting, holding office, and wearing the emblem or badge of Active Membership. A suitable emblem or badge of Junior Membership as adopted by the Institute may be worn by the Junior Members. When qualified, a Junior Member may apply for Active Membership, but must do so before reaching the age of 35, otherwise his membership shall expire.

Section 2. (*Applications.*) All applications for membership must be made to the Secretary in writing, and shall embody a concise

statement with the dates of the candidate's professional training and experience, and shall be in a form and in such detail as may be prescribed by the Membership Committee. The applicant for Active Membership shall give the names of at least five members to whom he is personally known. The applicant for Junior Membership shall give the names of at least five persons to whom he is personally known, two of whom shall preferably be members of the Institute. Each of these shall be requested by the Secretary to certify to the training, experience, professional attainment, and standing of the applicant. On receiving a favorable report from at least three of these references, the applicant shall be eligible to recommendation by the Membership Committee.

Section 3. (*Election of Members.*) At stated periods the Secretary shall mail to the members a ballot containing a list of all applicants who have been recommended by the Membership Committee. This list shall contain a detailed statement of each applicant's career and the names of the members who have vouched for him. All ballots shall be returned to the Secretary not later than three weeks after the date of issue. The ballots shall be canvassed by the Membership Committee, who shall report to the Council, who shall then declare each applicant elected for whom at least ninety-five per cent. of all ballots cast are in the affirmative. Provided, however, that any member voting in the negative may address a confidential letter to the Council, stating his objections to the candidate with evidence for the charges made. If the Council upon investigation considers such objections valid, they may declare an election void. A rejected candidate may make application again any time after one year. Persons elected to membership shall be notified at once by the Secretary. They must then subscribe to the rules of the Institute.

Section 4. (*Honorary Members.*) As the result of unusual ability and public recognition on the part of the industrial world, a person may, upon nomination of the Council and a vote of the Society at large, be made an Honorary Member, but at no time shall this number exceed five.

Section 5. (*Expulsions.*) For abuse or misuse of the privileges of the Institute or conduct unbecoming a member in the opinion of the Council, a two-thirds vote of the Council may expel any member of the Institute.

Section 6. (*Dues.*) The entrance fee for Active Members shall be $15.00; Junior Members shall pay no entrance fee; Annual dues

for Active Members $15.00, for Junior Members $10.00. Junior Members, on becoming Active Members, shall pay an entrance fee of $15.00 less $1.00 per year for each year of their membership as Junior Members. Provided, however, that no entrance fee shall be exacted until the Membership shall reach 200.

Any member may anticipate his dues for life by paying in advance such a sum as would be demanded by any reputable insurance association to yield an annuity equal to the annual dues from the time of the agreement until death. Upon resignation, or expulsion, all money so provided is to become the property of the Institute. Any person joining the Institute after the middle of the fiscal year is required to pay one-half of the dues only for that year. Any person in arrears for three months shall be notified by the Secretary. For non-payment at the expiration of one-half year, a member forfeits the right to vote or to receive the notices of the Association until dues are paid in full. All members are considered as such unless actual resignations are formally presented and accepted with the full payment of dues. On account of extenuating circumstances, dues may be remitted to any member by a two-thirds vote of the Council.

ARTICLE IV.

OFFICERS.

Section 1. The officers of this Society shall be a President, three Vice-Presidents, a Secretary, a Treasurer, an Auditor, and nine Directors. The officers shall be elected at the annual meeting. The President shall serve one year, the Vice-Presidents for three years each, and the Directors for three years each. The Secretary, Treasurer, and Auditor shall be elected for terms of one year each. At the first annual meeting one Vice-President shall be chosen for one year, one for two years, and one for three years. Three Directors shall be chosen for one year, three for two years, and three for three years. Thereafter, officers shall be chosen annually to serve full terms. The President, Ex-Presidents for the two years succeeding the expiration of their term of office as President, Vice-Presidents, Secretary, Treasurer, and Directors shall constitute the Council of the Institute. The President, Vice-Presidents, and Directors cannot be re-elected within the current twelve months from the expiration of term. The duties of office begin immediately after election and notification. An acceptance of office must be in writing addressed to the Secretary. Vacancies occurring in any office shall be filled by a majority vote of the Council for the

unexpired term. The duties of all officers shall be such as usually pertain to their offices or may be delegated to them by the Council or the Institute.

Section 2. (*Election of Officers.*) After the election at which this Constitution is adopted, the election of officers shall be by letter ballot. The Secretary, at least eight (8) weeks prior to each annual meeting, shall send to every member of the Institute a blank nominating ballot upon which the member may make nominations for the officers and Directors to be elected at the coming annual meeting. The nominating ballot is then to be properly signed and transmitted to the Secretary not later than five (5) weeks prior to the annual meeting. It shall then become the duty of the Secretary to prepare and issue an official ballot upon which shall appear the names of all nominations for office or for Directors which shall have appeared upon at least ten (10) nominating ballots. The official ballots shall be mailed not later than three (3) weeks prior to the annual meeting, one to each member, who shall properly signify on it his choice for the various offices and Directors, and transmit it to the Secretary. At the annual meeting the President shall appoint tellers to whom the Secretary shall deliver all the ballots received by him unopened, and who shall count and announce the vote.

ARTICLE V

COUNCIL

The Council shall have supervision and care of all property of the organization, and shall conduct its affairs according to the Constitution and By-Laws. At each annual meeting it shall present a statement of its proceedings during the year. Eight members of the Council called together by notice from the Secretary shall constitute a quorum, provided, however, that three members may be represented by proxy.

ARTICLE VI.

STANDING COMMITTEES.

The Council shall appoint the following committees:

1. Finance.
2. Committee on Meetings.
3. Publications.
4. Membership.
5. Library.
6 House Committee.

FINANCE COMMITTEE.

The Finance Committee shall have charge of the financial affairs of the Institute. This committee must prepare the budget and approve all expenditures. The Chairman of the Committee may be the Auditor of the Institute.

MEMBERSHIP COMMITTEE.

The Membership Committee shall be constituted of fifteen members, ten of whom may vote by proxy at any meeting. To the Membership Committee all applications for membership shall be referred. It is the duty of this committee to see that no person is admitted to the organization who is not qualified.

COMMITTEE ON MEETINGS.

This committee shall have charge of all meetings of the organization and shall fix dates and places of meeting.

COMMITTEE ON PUBLICATIONS.

This committee shall look after the papers presented to the Institute. If considered expedient, any or all of these papers may be published and distributed to members.

LIBRARY COMMITTEE.

This committee shall have charge of all permanent records, books, papers, pamphlets, etc., and shall obtain and place on file a complete record of all patent literature in reference to chemical engineering.

HOUSE COMMITTEE.

This committee shall look after the social affairs of the Institute, fixing the time and place of entertainments.

ARTICLE VII.

MEETINGS.

The annual meeting of the Association shall be held in December, the exact date to be fixed by the Council.

This Institute shall be governed by its Constitution in conformity with the laws of the United States. All questions shall be decided by majority of votes cast. The Institute shall not be held responsible for opinions expressed in papers. The name or use of the Institute shall not be tolerated for any commercial purpose.

Upon the adoption of this Constitution officers shall be elected immediately to hold office until the election and installation of their successors.

ARTICLE VIII.

AMENDMENTS TO THE CONSTITUTION.

Any member may propose an amendment by addressing the Secretary. At the first regular meeting thereafter the subject shall be discussed, and if worthy, notice to vote on same shall be posted until the next regular meeting, and written copy of the notice shall be sent to each member. The proposed amendment shall then be discussed in open meeting and can be passed by two-thirds vote of all members of the Institute as the result of letter ballot.

BY-LAWS

ORDER OF BUSINESS.

REGULAR MEETING.

Reading of minutes of last stated meeting.
Miscellaneous announcements.
Reading of papers, discussion, and communications.
Adjournment.

ANNUAL MEETING.

Reading of minutes of last stated meeting.
Miscellaneous announcements.
Stated business.
Annual reports.
Election of officers.
Address of retiring President, etc.
Adjournment.

In all questions requiring parliamentary ruling not provided for by the Rules of the Institute, "Robert's Rules of Order" shall be the governing authority.

OFFICERS AND COMMITTEES FOR 1911

COUNCIL

Elected at the New York Meeting, December 7, 1910

President,

F. W. Frerichs . . . . . 4320 Washington Bou., St. Louis, Mo.

Vice-Presidents,

George P. Adamson . . . . Easton, Pa.
Eugene Haanel. . . . . Ottawa, Ont.
Leo. H. Baekeland . . . . Yonkers, N. Y.

Secretary,

John C. Olsen . . . . . Polytechnic Institute, Brooklyn, N. Y.

Treasurer,

H. S. Renaud . . . . . 159 Front St., New York, N. Y.

Auditor,

Herbert Hollick* . . . . . Camden, N. J.

Ex-Presidents,

Samuel P. Sadtler. . . . . 39 South 10th St., Philadelphia, Pa
Charles F. McKenna . . . 50 Church St., New York, N. Y.

Directors for One Year

Brown, H. F. . . . . Wilmington, Del.
Reuter, Ludwig . . . . . Berkeley, Cal.
Smith, Thorn . . . . . Detroit, Mich.

Directors for Two Years

Baker, John T. . . . . Phillipsburg, N. J.
Grosvenor, Wm. M. . . . . 1123 Broadway, New York, N. Y.
Meade, Richard K. . . . . Allentown, Pa.

Directors for Three Years

Acheson, Edw. G. . . . . Niagara Falls, N. Y.
Booth, Wm. M. . . . . Syracuse, N. Y.
Hart, Edward . . . . . Easton, Pa.

COMMITTEE ON PUBLICATIONS

Mason, William P., Chairman
Andrews, L. W.
Bain, J. Watson
Grosvenor, Wm. M.
Hart, Edward
Kippenberg, Henry
Olsen, John C.

* Deceased.

MEMBERSHIP COMMITTEE

Langmuir, A. C., Chairman
Adamson, Geo. P.
Barton, G. E.
Bassett, W. H.
Bement, A.
DeCew, J. A.
Dow, A. W.
Hollick,* Herbert
Ittner, H. M.
Kaufmann. H. H.
Miner, H. S.
Olney, L. A.
Renaud, H. S.
Robertson, A.
Thompson, G. W.

COMMITTEE ON CHEMICAL ENGINEERING EDUCATION

Sadtler, S. P., Chairman
Booth, W. M.
Veillon, A. A. L.
Whitaker, M. C.
Wiechmann, F. G.

COMMITTEE ON MEETINGS

McKenna, Chas. F., Chairman
Andrews, L. W.
Booth, W. M.
Grosvenor, W. M.
Langmuir, A. C.
Meade, R. K.
Olsen, John C.
Sadtler, S. S.

FINANCE COMMITTEE

Hollick,* Herbert, Chairman
Adamson, Geo. P.
Dannenbaum, H.

COMMITTEE ON MEDAL

Booth, W. M., Chairman
Richards, J. W.
Robertson, A.
Sadtler, S. P.

COMMITTEE ON BOILER TESTS

Bement, A., Chairman
Booth, W. M.
Campbell, J. H.
Prentiss, Geo. W.

LIBRARY COMMITTEE

Alexander, Jerome, Chairman
Myers, Ralph E.
Olsen, J. C.

COMMITTEE ON MONOGRAPHS AND CATALOGUES

Grosvenor, W. M., Chairman
Bement, A.
Gibbs, A. E.
Hollick,* H.
Ittner, M. H.
Linder, Oscar

* Deceased.

LIST OF MEMBERS, JUNE, 1911

Honorary Member

CHANDLER, CHAS F., Columbia University, New York City.

Active Members

ACHESON, EDWARD G., Niagara Falls, N. Y.
President International Acheson Graphite Co.

ADAMSON, GEORGE P., 233 Reeder St., Easton, Pa.
Vice-President and General Manager, The Baker and Adamson Chemical Co.

ADGATE, MATTHEW, Naugatuck, Conn.
Supt. of the Naugatuck Chemical Co.

ALEXANDER, JEROME, 502 West 45th St., New York City.
Treasurer and Chemist, National Gum and Mica Co., National Glue and Gelatin Works

ALLEN, LUCIUS E., Box 22, Belleville, Ont., Can.
Consulting Chemical Engineer, Managing Director Ontario Limestone and Clay Co., Ltd., Belleville, Ont.

ANDREWS, LAUNCELOT W., 823 Brady St., Davenport, Ia.
President Andrews Chemical Works.

ARNOLD, CHARLES E., 602 West 20th St., Wilmington, Del.
Chemical Engineer for the E. I. du Pont de Nemours Powder Co.

AUSTIN, HERBERT, 485 North Main St., Fall River, Mass.
Chemical Engineer and Partner Manager of Ernest Scott & Co., of Fall River, Mass., and Montreal, P. Q.

AYER, ARTHUR W., 3403 Gray's Ferry Rd., Philadelphia, Pa.
General Supt., Harrison Bros. & Co.

BAEKELAND, LEO H., Yonkers, N . Y.
Research Chemist and Chemical Engineer.

BAIN, J. WATSON, University of Toronto, Toronto, Can.
Associate Professor of Applied Chemistry.

BAIRD, WILLIAM H., Rocky Ford, Col.
Gen. Supt. American Beet Sugar Co.

BAKER, JOHN T., Phillipsburg, N. J.
President J. T. Baker Chemical Co.

BARTON, G. E., 419 High St., Millville, N. J.
In charge of Laboratory and Dept. Mfg. Glass, Whitall Tatum Co.

BARTOW, EDWARD, Urbana, Ill.
Professor of Analytical Chemistry, Univ. of Ill. Director of State Water Survey of Illinois. Consulting Chemist with the Davenport Water Co.

BASSETT, WILLIAM H., Torrington, Conn.
Metallurgist American Brass Co.

BEBIE, J., 1800 South 2d St., St. Louis, Mo.
Chemical Engineer Monsanto Chemical Works.

BECK, ARTHUR G., Bay City, Mich.
Supt. and Chemist Hecla Co.

BECNEL, LEZIN A., 51 Arabella St., New Orleans, La., P. O. Box 390.
Chemical Engineer and Consulting Chemist.

BEERS, FRANK T., Washburn, Wis.
Supt. Barksdale Plant, E. I. du Pont de Nemours Powder Co.

BEHREND, OTTO F., Erie, Pa.
Vice-President and Treasurer Hammermill Paper Co.

BELDEN, ARTHUR WILLIAMS.
Engineer in charge, Technological Branch, U. S. Geological Survey, 40th and Butler Sts., Pittsburg, Pa.

BEMENT, A., 206 S. LaSalle St., Chicago, Ill.
Consulting Mining and Mechanical Engineer.

BJERREGAARD, A. P., 10724 Kimberley Av., N. E., Cleveland, Ohio.
Mfg. Chemist Canfield Oil Co., Cleveland, Ohio.

BOOTH, L. M., 136 Liberty St., N. Y.
President and Director, L. M. Booth Co., New York.

BOOTH, WILLIAM M., Dillaye Building, Syracuse, N. Y.
299 Broadway, New York, Consulting Chemist and Engineer.

BOWER, WILLIAM H., 2815 Gray's Ferry Rd., Philadelphia, Pa.
First Vice-President of Henry Bower Chemical Mfg. Co.

BROOKS, PERCIVAL C., Hegewisch, Ill.
Foreman Silicate of Soda and Chloride of Zinc Depts., General Chemical Co., Hegewisch Station, Chicago, Ill.

BROWN, H. F., Room 915 du Pont Bldg., Wilmington, Del.
Chemical Director, Smokeless Powder Dept., E. I. du Pont de Nemours Powder Co.

CAMP, J. M., Duquesne, Pa.
Chemist and Chemical Engineer, Duquesne Plant, Carnegie Steel Co.

CAMPBELL, JOHN HAYES, 5225 Fairmont Av., St. Louis, Mo.
Chemical and Metallurgical Engineer, Fredericktown, Mo.

CARNELL, WILLIAM C., Bridesburg, Philadelphia, Pa.
Chemist for Chas. Lennig & Co.

CATLIN, CHARLES A., 133 Hope St., Providence, R. I.
Chief Chemist and a Director of the Rumford Chemical Works.

CHUTE, HARRY O., 197 Pearl St., New York. Chemical Engineer.

CONVERSE, WILLIAM A., 2005 McCormick Building, Chicago, Ill.
Chemical Director Dearborn Drug & Chemical Works.

DANNENBAUM, HERMAN, Frankford, Philadelphia, Pa.
Vice-President National Ammonia Co.

DAVOLL, DAVID L., Jr., Guantanamo, Cuba.
Gen. Supt. and Chief Chemist Guantanamo Sugar Co.

DEAN, JOHN G., Parma, Mich.
Chemical Engineer for the Western Canada Cement & Coal Co., Ltd., and Allied Cement Companies.

DECEW, J. A., Canadian Express Bldg., Montreal, Canada.
Consulting Chemical Engineer.

DOW, ALLAN W., 24 E. 21st St., New York City.
Member of the firm of Dow & Smith, Consulting Engineers.

ELLIOT, ARTHUR H., Montclair, N. J.
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Second Vice-President, Roessler & Hasslacher Chemical Co.

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Herf & Frerichs Chemical Co.

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GRETH, J. C. WM., Pittsburg, Pa.
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GRISWOLD, THOMAS, Jr., Midland, Mich.
Engineer, The Dow Chemical Co.
Secretary, The Midland Chemical Co.

GROSVENOR, WM. M., 50 E. 41st. St., New York City.
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GUDEMAN, EDWARD, 903–4 Postal Telegraph Bld., Chicago, Ill.
Consulting Chemist and Chemical Engineer.

HAANEL, EUGENE, Dept. of Mines, Ottawa, Ont., Can.
Director of Mines, Dept. of Mines, Ottawa, Ont., Can.

HARRIMAN, NORMAN F., Union Pacific Laboratory, Omaha, Neb.
Chemist and Engineer of Tests, Union Pacific R. R. Co.

HART, EDWARD, Easton, Pa.
Prof. Chemistry, Lafayette College; President Baker & Adamson Co.; Prop. Chem. Pub. Co.; Consulting Engineer.

HEBDEN, JOHN C., Box 465, Providence, R. I.
Vice-President and General Manager Franklin Process Co.

HOLLANDER, CHARLES S., Hartford, Conn.
Secretary and Chief Chemist Eastern Chemical Works, Inc., Hartford, Conn.

HOLLICK,* HERBERT, The Robeson, Camden, N. J.
Supt. Moro Phillips and U. S. Works of General Chemical Co.

HOWARD, HENRY, 36 Amory St., Brookline, Mass.
Vice-President Merrimac Chemical Co.

HUGHES, LOUIS S., Joplin, Mo. Chief Chemist, Picher Lead Co., Joplin, Mo.

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Chief Chemist, Eastern Branch, Corn Products Refining Co.

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ITTNER, MARTIN H., Colgate & Co. Jersey City, N. J.
Chief Chemist, Colgate & Co.

JAMES, JOSEPH H., Pittsburg, Pa.
Prof. Chemical Engineering Practice, Carnegie Technical Schools.

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JONES, L. C., Syracuse, N. Y.
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Gen. Mgr. Mutual Chemical Co. of America.

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Director of Laboratories, Johnson & Johnson, New Brunswick, N. J.

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Consulting Chemical Engineer, Industrial Testing Laboratory.

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Supt. of Chemical Manufacture at Rahway Plant of Merck & Co.

LAMAR, WILLIAM ROBINSON, 8–14 Johnson St., Newark, N. J.
President Lamar Chemical Works.

LANGMUIR, ARTHUR C., 9 Van Brunt St., Brooklyn, N. Y.
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LEE, FITZHUGH, Grasselli Chemical Co., Cleveland, Ohio.
Assistant Chairman Manufacturing Committee, Grasselli Chemical Co.

LE MAISTRE, F. J., Ridley Park, Del. Co., Pa.
Chemical Engineer, E. I. du Pont de Nemours Powder Co.

LESSNER, C. B., Carril, Spain.
Manager of the Carril Works and Chemist to the San Finx Tin Mines. Ltd., and Metallurgical Chemist to the Angelita Mines.

LE SUEUR, ERNEST A., 50 McLaren St., Ottawa, Ont., Can.
General Manager and President of the General Explosives Co., Ltd.

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* Deceased, May 4, 1911.

LIHME, IENS P., Grasselli Chemical Co., Cleveland, Ohio.
Engineer, Grasselli Chemical Co.

LINDER, OSCAR, 56 North Waller Ave., Chicago, Ill.
Works Chemist, Western Electric Co., Hawthorne Works.

LUNDTEIGEN, A., Union City, Michigan.
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MALLINCKRODT, EDWARD, St. Louis, Mo.
President Mallinckrodt Chemical Works.

MARSH, CLARENCE W., Niagara Falls, N. Y.
Chief Engineer The Development and Funding Co., New York City.

MASON, WILLIAM P., Troy, N. Y.
Prof. Chemistry, Rensselaer Polytechnic Institute.

MCCORMACK, HARRY, Armour Institute, Chicago, Ill.
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Asst. Supt. Open Hearth Department Granite City Steel Works Branch of the National Enameling and Stamping Co.

MINER, H. S., Gloucester City, N. J.
Chief Chemist Welsbach Light Co.

MINOR, JOHN C., Jr., Saratoga Springs, N. Y.
Manager, New York Carbonic Acid Co.

MYERS, RALPH E., 31 Franklin Av., East Orange, N. Y.
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OLNEY, LOUIS A., Lowell Textile School, Lowell, Mass.
Professor of Chemistry and Head of the Department of Textile Chemistry and Dyeing, Lowell Textile School; Chemist Lowell Gas Co.

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Chief Chemist, C., M. & St. P. R. R.

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REUTER, LUDWIG, Berkeley, Cal.
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ROBERTSON, ANDREW, 2 N. 9th St., Richmond, Va.
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ROESSLER, FRANZ, 89 High St., Perth Amboy, N. J.
Vice-President and Secretary, Roessler & Hasslacher Chemical Co

ROSENGARTEN, GEO. D., Box 1625, Philadelphia, Pa.
Vice-President The Powers-Weightman-Rosengarten Co.

PROCHAZKA, GEORGE A., 138 West 13th St., New York.
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SADTLER, SAMUEL S., 39 South 10th St., Philadelphia, Pa.
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Analytical and Consulting Chemical Engineer and Assayer.

SHIMER, PORTER W., Easton, Pa.
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SIMMONS, W. H., Fenton, Mich. Supt. Badger Portland Cement Co.

SIMPSON, EDWARD H., Westside Ave., Jersey City, N. J.
Manager Arlington plant of the Mutual Chemical Company of America.

SMITH, FRANCIS PITT, 24 East 21st St., New York City.
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SMITH, HARRY E., 36 Beeresford Pl., East Cleveland, Ohio.
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Chief Chemist and Manager Lard and Oil Depts., Halsted & Co., Jersey City.

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Diack & Smith, Consulting Chemists.

STILLMAN, JOHN MAXSON, Stanford Univ., Cal. Professor of Chemistry.

TAKAMINE, JOKICHI, 520 West 173d St., New York City.
Consulting Chemist for Parke-Davis & Co., Detroit, Mich.

TAYLOR, EDWARD R., Penn Yan, N. Y. Manufacturing Chemist.

TAYLOR, JOHN, 820 W. 7th St., Des Moines, Iowa.
Manager Iowa Portland Cement Co.

TEAS, WILLIAM H., Ridgway, Pa.
General Supt. U. S. Leather and Allied Companies.

THOMPSON, GUSTAVE W., 60 So. Portland Ave., Brooklyn, N. Y.
Chief Chemist, National Lead Co.

THORP, FRANK H., Boston, Mass.
Asst. Prof. Industrial Chemistry, Mass. Inst. Tech.

THIELE, LUDWIG A., Holland, Mich.
General Manager of the Holland Gelatine Works, Holland, Mich.

TOCH, MAXIMILIAN, 320 Fifth Ave., New York City.
Member of firm of Toch Bros.

TRAUTWEIN, A. P., Carbondale, Pa. Pres. Carbondale Instrument Co.

TUFTS, JOHN L., Winchester, Mass. Chemical Engineer.

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VEILLON, A. A. L., 1800 South 2d St., St. Louis, Mo.
Vice President and Works Manager, Monsanto Chemical Works.

VORCE, L. D., 364 Grand Boulevard, W. Detroit, Mich.
Supt. of Pennsylvania Salt Mfg. Co., Supt. of Goldschmidt Detinning Co., Gen. Supt. Wyandotte Southern Ry. Co.

WAGNER, THEODORE B., Heyworth Bldg., Chicago, Ill.
Operating Committee, Corn Products Refining Co.

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WHEELER, FRANK G., Trenton, Mich.
Chemist with the Penn. Salt Mfg. Co., Wyandotte, Mich.

WHITAKER, M. C., Columbia Univ., New York City.
Professor of Engineering Chemistry, Columbia Univ. Editor of Jour. of Ind. and Eng. Chemistry, Consulting Chemical Engineer.

WIECHMANN, FERDINAND G., 301 W. 106th St., New York City.
Consulting Chemical Engineer.

WITHROW, JAMES R., Ohio State Univ., Columbus, Ohio.
Associate Professor of Chemistry, Consulting Chemical Engineer.

ZWINGENBERGER, O. K., 106 Fulton St., New York City.
Chemical Engineer

JUNIORS

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Chemist in charge of Manufacturing with the Mallinckrodt Chemical Works.

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TURNER, NORMAN L., Bellville, Ontario, Can.
Provincial Assayer of Ontario, Can.

WHITCOMB, L. R., 100 William St., New York.
Chemist and Bacteriologist in charge of Testing Lab., for Nicholas S.Hill, Jr.

In Memoriam

Herbert Hollick, born at Earlswood Terrace, London, Sept. 21, 1866. Elected courses in chemistry, physics, etc., at Kings College, London, 1883 to 1886. Matriculated as a student in the University of London, July 27, 1887. After pursuing the chemical course at Kings College, London, entered business with his father, John Hollick, a cement manufacturer of London, and remained in that association until he came to the United States in 1895. For a short period after arrival, Mr. Hollick was connected with a cement company near Easton, Pa. In January, 1897, he entered the employ of the Nichols Chemical Co. as a chemist for the Sulphuric Acid Works at Syracuse, N. Y. At the time of the formation of the General Chemical Co., in 1899, the above-mentioned works was purchased by the new company, and Mr. Hollick retained his previous position for a few months. During the latter part of 1899, Mr. Hollick was transferred to the Moro Phillips and United States Works of the General Chemical Co. at Camden, N. J., taking the position of superintendent, which position he filled until his death, May 3, 1911.

His death was due to heart failure, following an attack of pneumonia. The Institute has suffered the loss of an enthusiastic and faithful member in his death.

ADDRESSES AND PAPERS

READ BEFORE THE INSTITUTE

THE EVOLUTION OF PORTLAND CEMENT PROCESSES

Address by President McKENNA

Delivered at the New York Meeting, Dec. 7, 1910

In the Portland cement industry there is a perpetual but healthy unrest. No sooner is one feature of marked improvement successfully brought forward producing a suggestion of finality than several minor progressive steps are seen to tend together toward such economic advantages as to again constitute practically a new process. On reviewing the subject I have felt that the history has the elements of a romance, if it were not for the overpowering newness of it all, and I have felt that the near future still has surprises in store.

I hope I may leave this impression upon you, and also in rehearsing it, I hope to show properly that, while praise is due to the mechanical engineer, it must also be given to the chemist. Indeed, it is generally felt to-day that it is to chemical engineering that the industry must appeal most strongly in the future, and that progress and economy is promised more surely because the leaders have realized that the trained and experienced chemical engineer is best fitted to cope with the new problems and avoid some errors similar to those of the past.

We have seen a product obtained in a most primitive fashion only fifty years ago now produced throughout the world in millions of tons annually, and with such economy that for one cent 12 lbs. of raw material will be taken from the earth, dried, ground, calcined and vitrified, and the product ground again. It would seem as if the use of fuel, machinery, human hands and human brains could not go further. Yet there is ample scope for improvement and economies, as you will easily perceive.

Aspdin's invention seemed a simple one (Fig. 1). He pulverized limestone, burned it, mixed clay with it and water to a

plastic mass, after which this was dried and burned in a kiln and the product pulverized.

Much experimenting had previously been done by himself and by many engineers throughout the world to try to discover the cause for hydraulicity, but beyond perceiving the value of the argillaceous elements in the limestone, none of them discerned the important part played by high temperatures in the burning. Aspdin was the first to combine these elements properly as well as to properly burn much of the cement. It is very probable that he did not know that the vitrified pieces of his clinker made the only true Portland cement. It is also

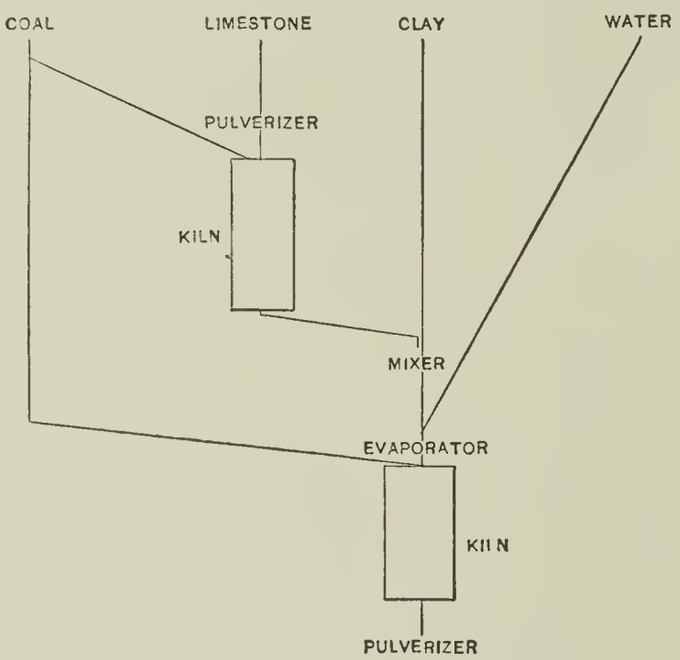

FIG. 1.—Aspdin Patent, 1824.

very probable that other experimenters had obtained vitrified Portland clinker when burning natural argillaceous limestone and did not recognize its special value.

The success of Aspdin's work was noted in other countries, but for the first twenty-five years its greatest vogue was in England. Many modifications had in the meantime been introduced there and the typical English process of the day was one (Fig. 2) in which chalk and clay were introduced with an excess of water into wash mills—large circular basins with revolving harrows—and after being incorporated there, transferred to large backs or settling reservoirs, from which the surplus water was drawn off. It took about six weeks to settle. The stiff mud from these was dried on floors heated from below and then charged into the

kilns in which coke or coke dust was the fuel. The product was ground by burr stones. The juxtaposition of chalk deposits near the Thames and the Medway and the mud banks of these rivers, together with a plentiful supply of coke from the gas works of London caused a large development of this industry near the world's greatest city.

About the middle of the last century the industry was fairly started in Germany and was destined there to take a development characteristic of that country. Here the skill of the chemist was successfully given free scope. The favorite method ultimately

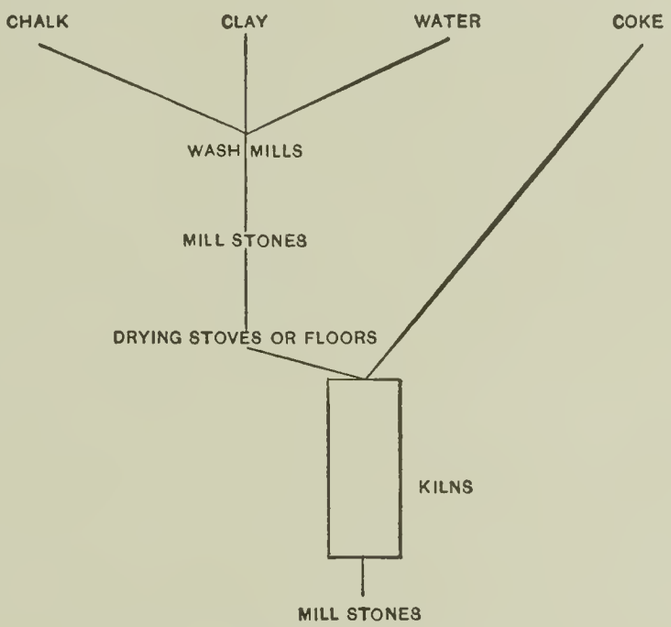

FIG. 2.—Old English Process.

developing in Europe (Fig. 3), sometimes called the semi-wet process, was one in which less water was used in the beginning, and in which an incorporating mill was used on the stiff mixture. This saved the time previously allowed for the very wet mixture to settle in the backs. When you add good chemical control of the original proportions and this feature of incorporation by grinding you see how progress was being made. This is what the Germans particularly did.

The kilns first used were the ordinary lime kilns, subsequently increased in height for the purpose of increasing the heat. Later in some of the greatest of the German works the Hoffman continuous kiln (Fig. 4) was much used in which compartments are charged and discharged and the flat roof used for drying.

In Germany the Dietzsch became the favorite in later years. In this kiln (Fig. 5) the material is preheated in the upper part

as usual, and in the central part into which it is drawn by the workmen operating through the fire door it is particularly exposed

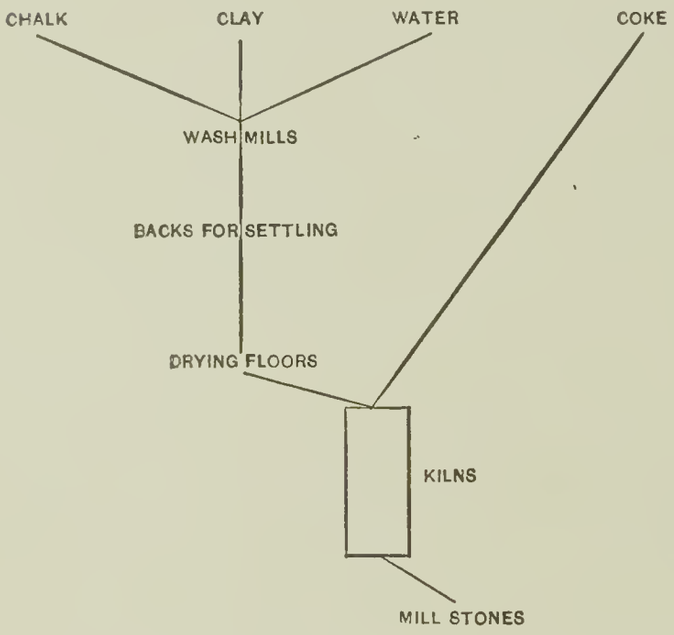

FIG. 3.—Later English and Continental Process, Semi-wet, after 1870

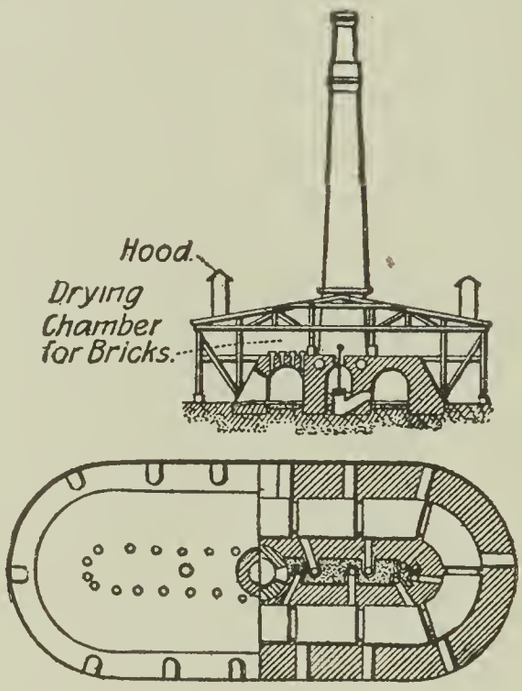

FIG. 4.—Hoffman Continuous Kiln.

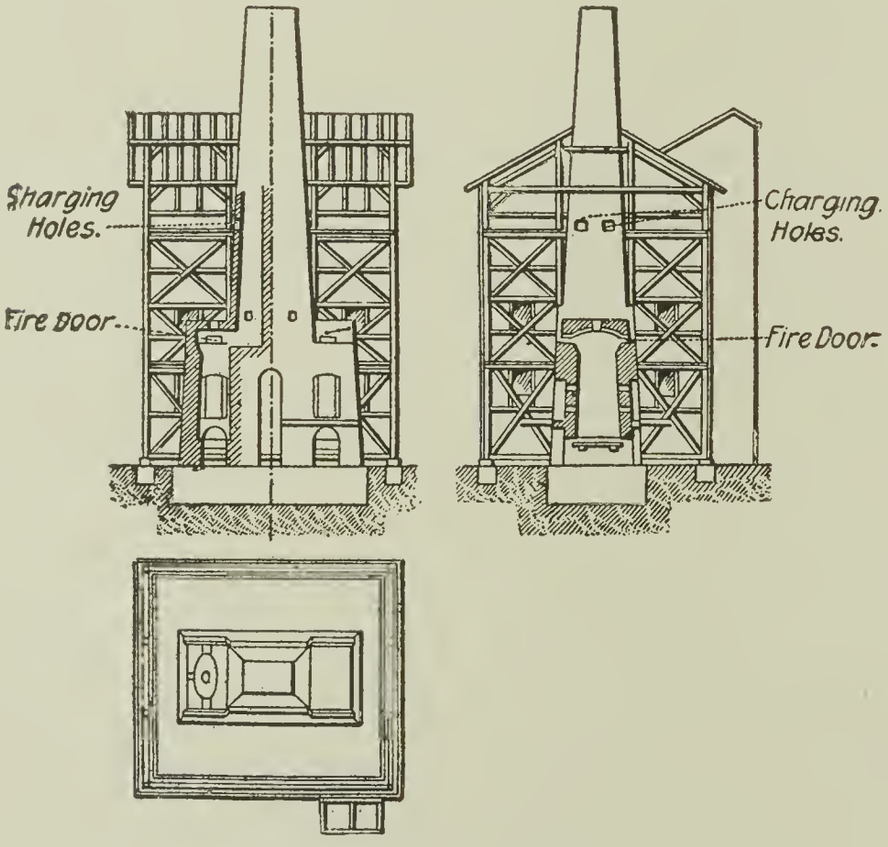

FIG. 5.—Dietzsch Kiln

to high heat by reason of the form of construction of the furnace here. The clinker gradually cools as it sinks below.

The Schöfer or Aalborg kiln is an upright one like the Dietzsch and has a zone of high heat.

In this country investigators during the decade after the close of the Civil War, noting that the Portland cement imported from Germany and England was selling for $5 a barrel, sought eagerly for materials from which to make it. It was thought that a soft chalk must be found before any economical works could be thought of. This was the view of all English cement-makers who were visiting this country at one time with a view of starting business.

But David F. Saylor, who was making natural cement from one kind of rock at Siegfried's Bridge, near Allentown, Pa., began

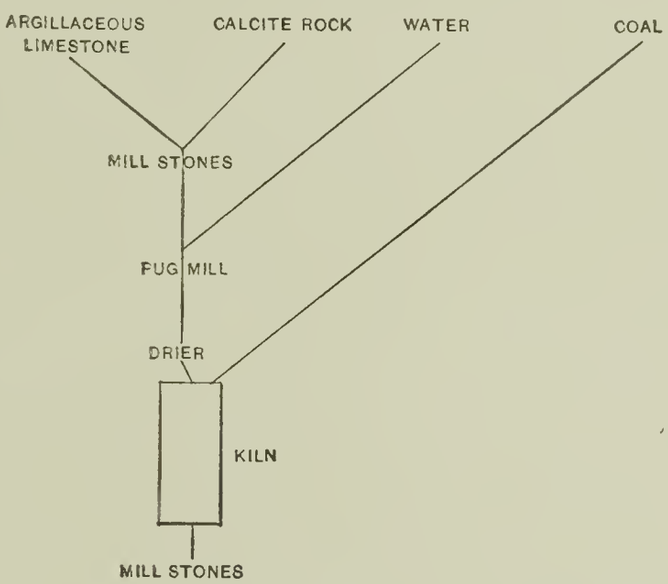

FIG. 6.—First American Process (Saylor, about 1875).

experimenting in the early seventies upon a mixture of this rock with a purer limestone. He produced in effect a true Portland cement (Fig. 6) and he was destined to be the first in a long line of American inventors, each of whom can be said to have modified the industry so fundamentally and markedly as to lead the world in each step forward. The first kiln used to produce Portland cement in America was a bottle kiln of the type used in England. Subsequently at Coplay, Pa., the seat of the industry, the Schöfer kiln was built.

Saylor's American Portland was the recognized and only important American Portland cement for a few years till Antonio Navarro, a capitalist, entered the business. Ransome had patented a rotary kiln in England in the seventies, but it was not practically adopted there. In the early eighties Navarro secured the American

rights, and what is now the present Atlas Portland Cement Company, was started at Northampton, Pa. Whittaker also used a similar kiln and both of these used oil as a fuel. This was entirely a dry process (Fig. 7). It is sometimes thought that in no country but America was it the practice in those days to eliminate the wash mill and to incorporate dry. This is not so; for in Europe from 1885 to 1895 there were several plants operating on nearly the same process: first, crushing and pulverizing dry; second, mixing and moistening with about fifteen per cent water; third, molding into bricks; fourth, burning; fifth, grinding clinker.

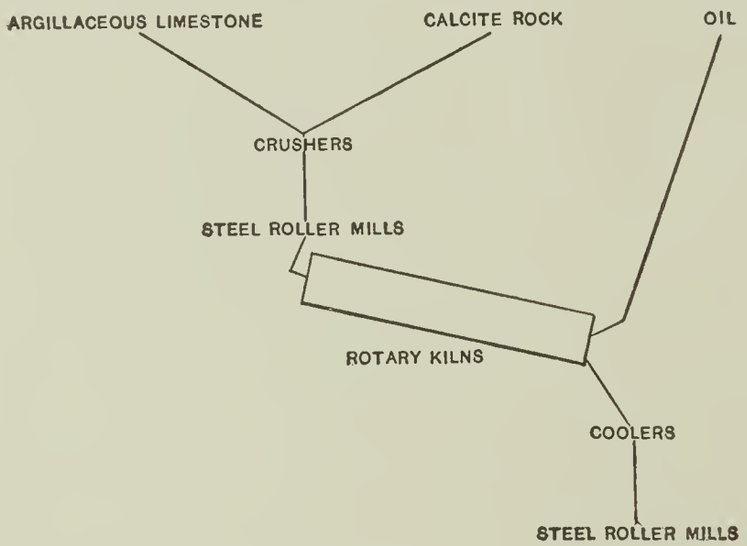

FIG. 7.—Early American Dry Process (about 1890).

In 1895 Hurry and Seaman were amongst the first to operate in this country by a process which was destined to be of great influence the world over in the industry. This was the process for using as the fuel powdered coal blown into the kilns. The product was so well burned and so large an output was continuously produced that the method rapidly extended. The clinker thus produced made a cement which was very quick setting. If a change in composition of the raw materials was made to avoid this, the cement was unsound (particularly upon trial by the quick method of being exposed to boiling water or steam). Then it became the custom to do here what had for some time been practiced in Europe, namely, to add plaster of paris or fine ground gypsum to the extent of one and one half to two per cent to the ground cement, which modified this phenomenon materially (Fig. 8) and produced a hydraulic substance of very desirable qualities.

A little later, almost within the last twelve years, it was dis-

covered that the raw materials must be very finely ground if a perfect clinkering is to be secured. The wet method of the European works did good incorporating, and if this is desired in the dry process and the quick-acting rotary kiln, the material must be ground exceedingly fine. Also, if the cement is coarse it will hydrate slowly, with disastrous results of expansion. This was the heyday of the mechanical engineer.

These details of fine grinding had been neglected by the European practitioners of the art, but really explained their troubles. Their raw materials had been all right, because they had chalk and clay which facilitated wet grinding. The incorpora-

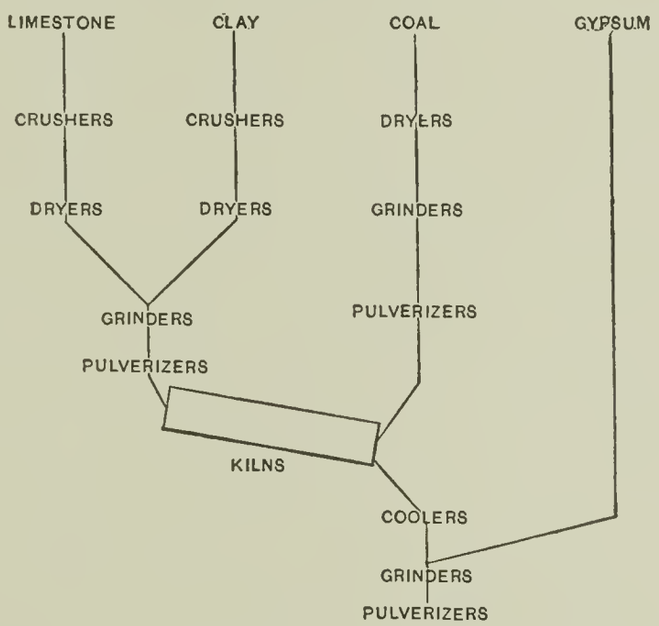

FIG. 8.—Modern World-wide Process, Dry Material.

tion was good and the clinkering consequently was good, but their cement was frequently bad because it was coarse. Immediately a great variety of milling apparatus was invented. The American mechanical engineers worked hard upon this problem with great success. The inventing and improving of this class of apparatus is still going on. The one kind of mill, modified, will serve for both raw and clinker grinding.

Two important classes of milling apparatus have been brought into use in this industry. The development of flour milling when away from stone mills was towards steel roller mills, but in the cement industry the development of two important classes of comminuting apparatus resulted from the abandonment of stone mills. (It is true, stone mills are not yet entirely antiquated, for a new mill at Norfolk has just been equipped with everything

of most modern form except the mills, which are burr-stones and which on experiment have proven to give satisfaction for the material operated on—marl—an interesting reversion!)

Of the new classes of mills referred to we have those of that type to which belong the Griffen, the Fuller, and the Kent mills, in which revolving steel shoes or balls press against a steel die or channel. The Fuller, using balls, is highly efficient, particularly in producing a high percentage of the finest flour of cement.

The other type requires two separate installations, namely, a large drum lined with steel plates and partially filled with steel balls, to do the comminuting of rocks coming from the coarse grinders, and a long horizontal drum partly filled with large quartz balls to do the pulverizing.

But the genius of Edison was now introduced upon the stage and in the first years of the century, after improving the large crushing machinery, he turned his attention to the improvement of the kilns. The prevailing length at this time was 60 ft., with an output of about 180 barrels per day and a coal consumption of 125 lbs. per bbl. Some kilns 100 ft. long and 7 ft diameter had been used in Europe on wet materials. Edison believed that if the kiln were 100 ft. long the product would be larger, the cement better and the coal consumption less. He has proven these points. But even with this economy the fuel consumption was three times the theoretical and twice what it should be practically. Immediately interest was centered upon the economics of fuel consumption in the Portland cement kiln.

It is admitted that the greatest avoidable loss is in the stack gases; next, the loss of radiation, and lastly, the heat carried off by the clinker. The last named has been most often attacked. Losses by radiation have been lately considered by inventors, but not yet successfully obviated, principally on account of the dilemma or choice between overheating the lining or overheating the shell. The losses in the stack gases have been diminished by careful attention to the details of burning, and lately it is believed by still further lengthening the kiln. One or two kilns here and some abroad, are said to be now operated experimentally on a length of 235 ft., more or less, but results are not divulged. Strange to say, it is my belief that economies in coal, taken as a whole (that is, the coal for power and the coal for burning) will

be improved by returning to the wet process. Before describ ing this I will speak of another process that marks an important epoch.

One of the greatest developments in Portland cement manufacture in this country has emanated from the steel works. Blast furnace slag, particularly when treated by water when hot and then granulated, has many virtues for the alumina-silicate element in a hydraulic compound with lime. This was the old slag cement, but deserves no further mention in that the composition and the reactions of that product are entirely different from Portland cement, belonging rather to the class puzzolana cement, with which Roman engineering accomplished much.

But investigators both here and abroad labored to produce clinker from a mixture of slag and limestone, and with the high heat of the rotary kiln they have been able to do it. It differs little from the standard process except that the slag is the clay element and is at once ready for pulverizing, and that Kent mills, together with air separators, are used for finishing. This process has a thermal advantage, both in the fact that part of the lime has been calcined, and part of it is in favorable form of combination with the silica and alumina. Other advantages possessed by a steel works in making slag Portland cement are that the slag used would otherwise be a costly nuisance and the important advantage of having blast furnace gas for the production of power. The manufacture of cement under these conditions is so favorable a proposition for the United States Steel Company that it is rapidly becoming the largest factor in the business. The environs of Chicago are producing almost as much cement as the whole of the Lehigh Valley.

Besides mixtures of clay and limestone, argillaceous limestone and pure limestone or calcite, slag and limestone, we have also as materials shale and limestone and clay and marl. The shale and limestone introduce no complexity or important change from the type modern process except in the drying and grinding. The marl, or what might be called *bog calcite*, has always been a different proposition. One of the important events which I have not previously mentioned, in the history of American Portland cement industry, was the work of Millen and others in Central New York State, where such marls are plentiful. They struggled in the same way as Saylor and at the same time, and really manu-

factured on a commercial scale, but one by one succumbed to the competition of the Lehigh Valley material. The latest to close, the Empire at Warners, N. Y., was a very important factor for some years, producing a good cement in rotary kilns, but under severe economic difficulties. Michigan suffered most from the false hopes held out of profit from her marl beds.

Now, it would seem strange to admit that wet marl costs too much to dry or to put in the kiln in a slurry, and then to claim that grinding into a semi-wet mix hard and almost dry rock and clay, or rock and shale, is a good economical proposition. Yet the truth of this is coming to be recognized. A company operating in one of the eastern states built a wet plant for limestone and clay a number of years ago, and although their handicaps were great, they have succeeded by persistent effort at improvement and are about to obtain great aid from the introduction of the long kiln.

American cement engineering advanced beyond European ten years ago. To-day European practice is in advance, and it is on account largely of improving in details on the American ways that most is promised from current practice in the wet way. The explanation is this: the physical character of marl prevents the easy removal of water and also causes a slurry to carry too much water—almost sixty per cent.

The reason why wet processes failed was because no account was taken of this excess water even in the so-called semi-wet slurry. When it was realized that this proportion of water should be cut down, it was found that slurry with forty per cent water could be pumped. But it was also found that a great deal depends upon the physical character of the raw constituents. There are some hard materials like limestone and shale, wherein thirty-five to thirty-two per cent and even a little less may yet permit the free movement and carriage of the slurry. Great attention must be paid to the fineness to succeed in attaining this minimum water. Thus the consumption of 200 lbs. of coal formerly recorded against the rotary kiln in the wet method must be materially reduced. Then adopting the advantages of the long kiln for large capacity and for full utilization of heat, eliminating also coal for the dryer and the wet process for hard materials becomes not only feasible but highly desirable.

In most modern European mills there is provision for drying

in rotary driers between the kiln and the stack and also for saving clinker heat by under coolers taking the air for combustion first over the clinker and closing up air leaks in the front of the kiln. (Figs. 8*a* and 8*b*.)

Then we have other factors which are important, and in these I believe a well-designed wet process introduces promise of saving. The first is raw grinding. With greater capacity of mills for equal horse-power we shall have made a gain. It was admitted when marl or chalk or clay were used, that the wet grinding was done at an advantage. It is so with the hard stone; after crushing, the pulverizing wet will be done more economically. In an experiment with the pebble mill of F. H. Smidth & Company the following results were obtained:

Fineness obtained, Residue on Sieve No. 18c	Product.	
	Wet Grinding.	Dry Grinding.
13.0 per cent	100% of pebble weight	73% of pebble weight
8.0 "	70% " " "	54% " " "

Secondly, it is safe to say that the fuel requirement in the kiln will be less by reason of the intimate contact of the particles of stone and clay—the rearrangement of the molecules in the clinkering stage will require less heat. This clinker also grinds more easily than that from less well compounded dry materials requiring high vitrification. Then there is no drier installation and no coal to be burned for it. There is no dust at the driers. The dust nuisance, in fact, is more than half eliminated in a wet mill. This is of considerable importance in reducing losses to machinery and the actual loss of the dust itself, which carries with it the cost of royalty, quarry, drier and grinder, and is a nuisance to the neighborhood. The dusty appearance of the air around a group of cement mills is a joy to all interested in the industry as a sign of prosperity, but it is not pretty. We ought to pay dividends in esthetic currency whenever we can spare some—for outsiders.

This process has been placed on an economical basis by the advances made in the design and construction of rotary kilns which have been brought to such a point of perfection that it

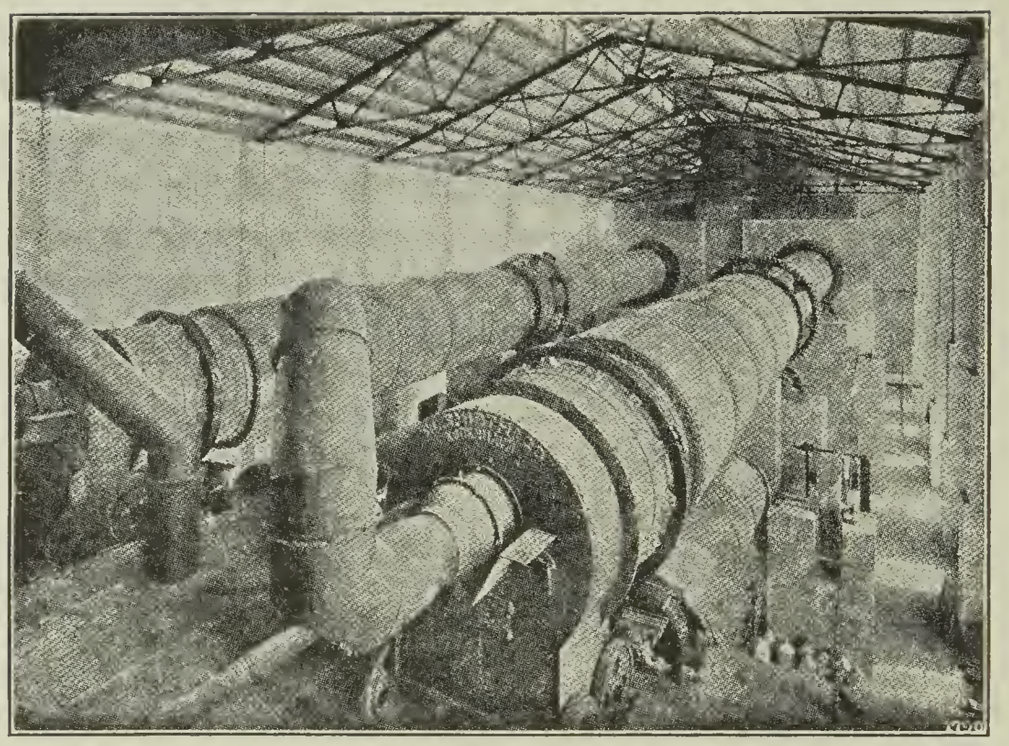

FIG. 8*a*.—Rotary Kilns with Enlarged Burning Zone and Compressed Air Firing at the works of Noerresundby Portland Cement-Fabrik, Noerresundby, Denmark.

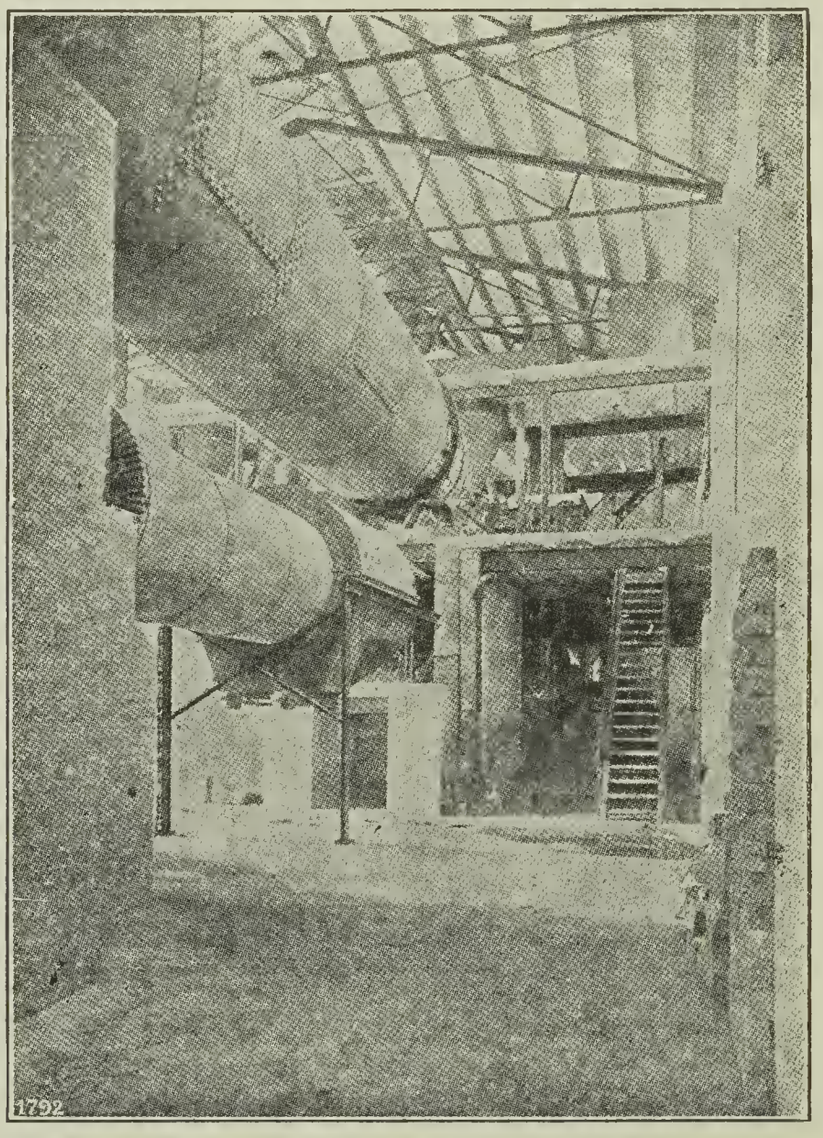

FIG. 8*b*.—Rotary Kiln of Noerresundby Portland Cement Fabrik, Noerresundby, Denmark.

The Rotary Kilns are equipped with enlarged burning Zone, Compressed Air firing and under Coolers.

is possible to have wet mixtures containing between thirty and thirty-five per cent of moisture with the same economy and to obtain the *same capacity* as can be had from modern rotary kilns on the dry process. The following is the record of the perform-

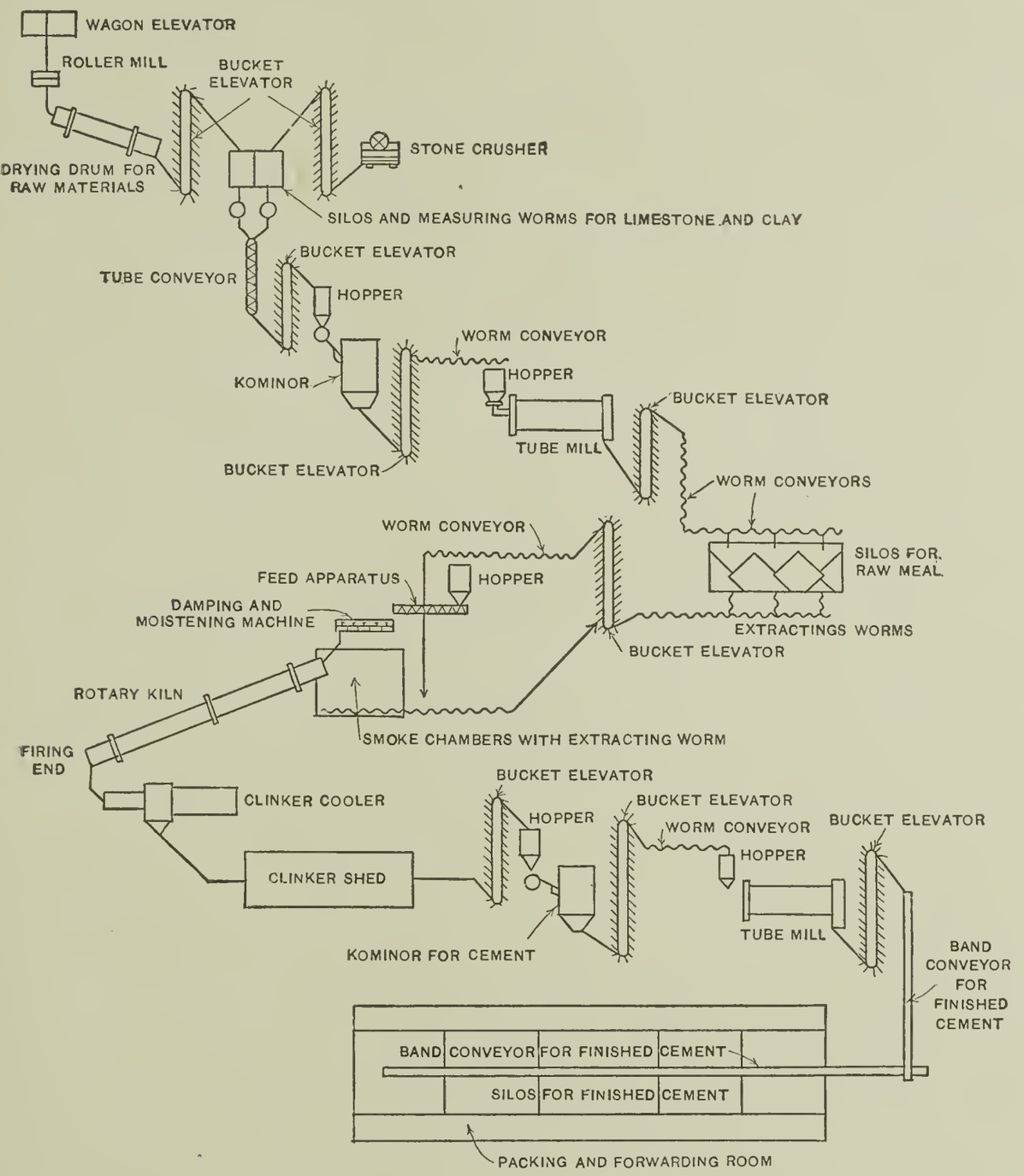

FIG. 6.—Diagram of Modern Cement Manufacture, Dry Process.

ance of a kiln in a modern mill in Russia working the wet process on a slurry of thirty-eight per cent water made from hard raw materials.

The kiln was 150 ft. long, with enlarged burning zone from 6.9 ft. in diameter to 7.9 ft. in diameter. In working 26 days it pro-

duced 14,500 barrels of 380 lbs. each, or about 560 barrels per day, with a coal consumption of 24.2 per cent, or about 92 lbs. per bbl. This coal contained 1.42 per cent water, and on the dry basis had a heat value of 11,500 B.T.U.

Much advance is being made in the study of the heat economics of the kiln, and the researches of Newberry, Meade, Richardson and Landis are carrying us forward by placing more accurate data

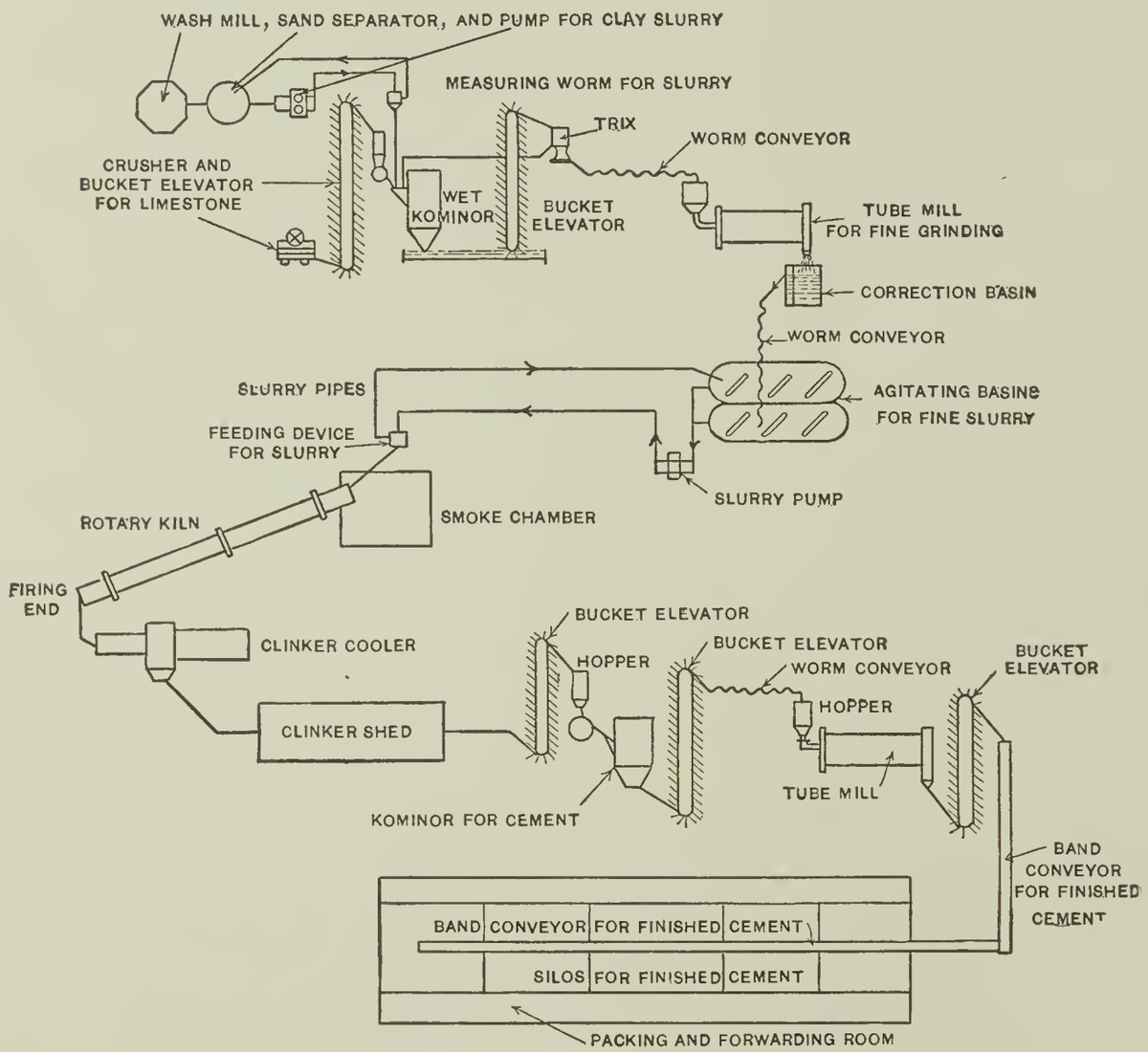

FIG. 10.—Diagram of Modern Cement Manufacture, Wet Process.

before us. In good present dry practice, in kilns 135 ft. to 150 ft. long, we are producing 700 barrels of cement daily with a kiln coal consumption of 85 lbs. per barrel. The product is ground to pass eighty per cent through a No. 200 sieve. Some mills are probably doing this at a mill cost of 60 cents. I have seen figures of some which indicate that 50 cents has been reached in the best situated and best engineered plants, and that the given good installation could do this in a given good situation for coal and raw material.

But the coal and the power draft are still the items promising improvement.

As said before, power should be saved by wet grinding; it should be saved in grinding so-called wet-process clinker. Again, there is something promised in the way of a new discovery in pulverizing which will increase mill capacity very materially, it is claimed. This is the substitution, in place of part of the

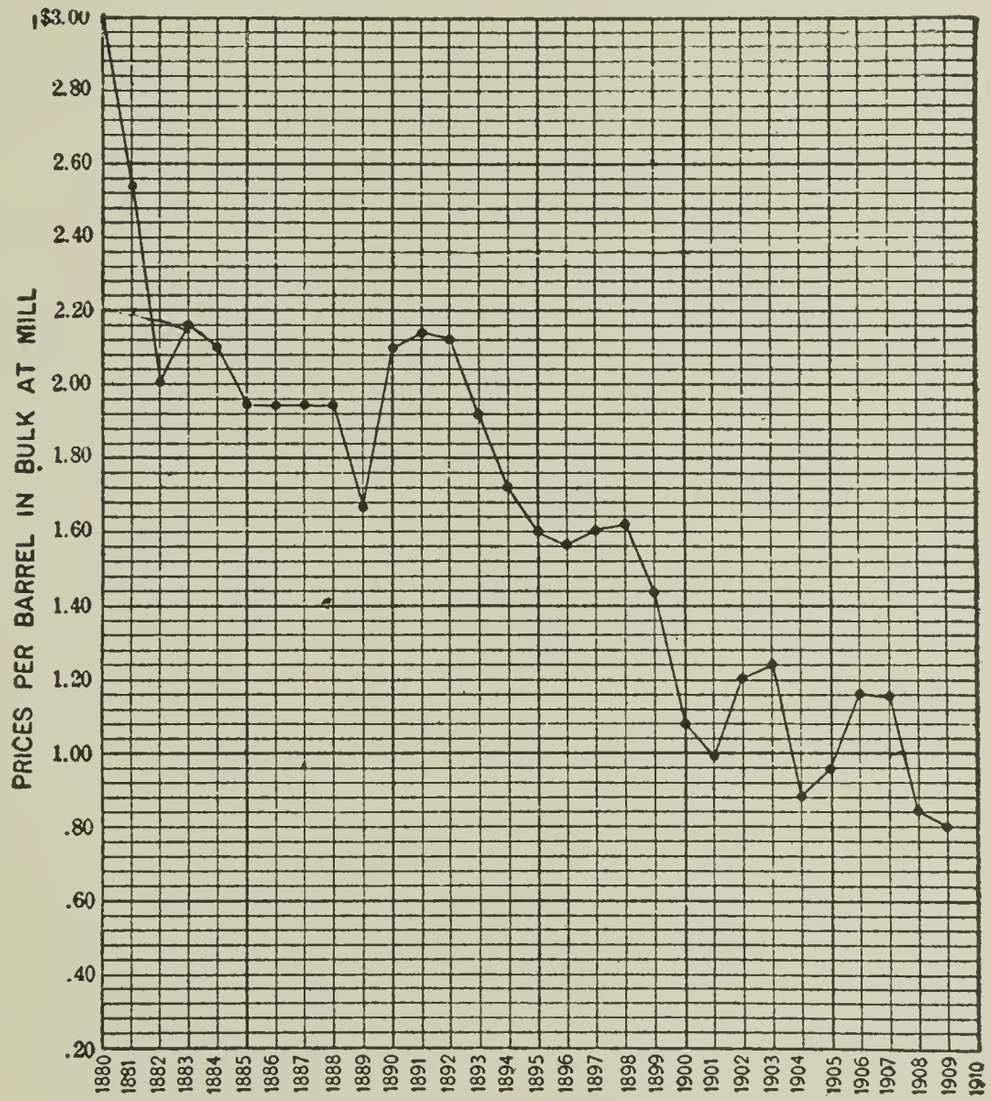

FIG. 11.—Price Curve of Cement from 1880—1909.

usual charge of pebbles in the discharge end of the tube mill, of some hard metal cylinders which, being separated from the pebbles by a screen, complete the pulverizing more perfectly and with less power.

The saving of heat from the clinker will improve in details of apparatus and considerably in efficiency. Professor Landis says that 10 lbs. of coal are lost by heat of clinker and that from 5 to 7 lbs. can be saved by efficient undercoolers. He has also

made the important discovery that much more heat than we had supposed is generated by the formation of clinker. It is so large that in a theoretically perfect condition, with no losses, the reac-

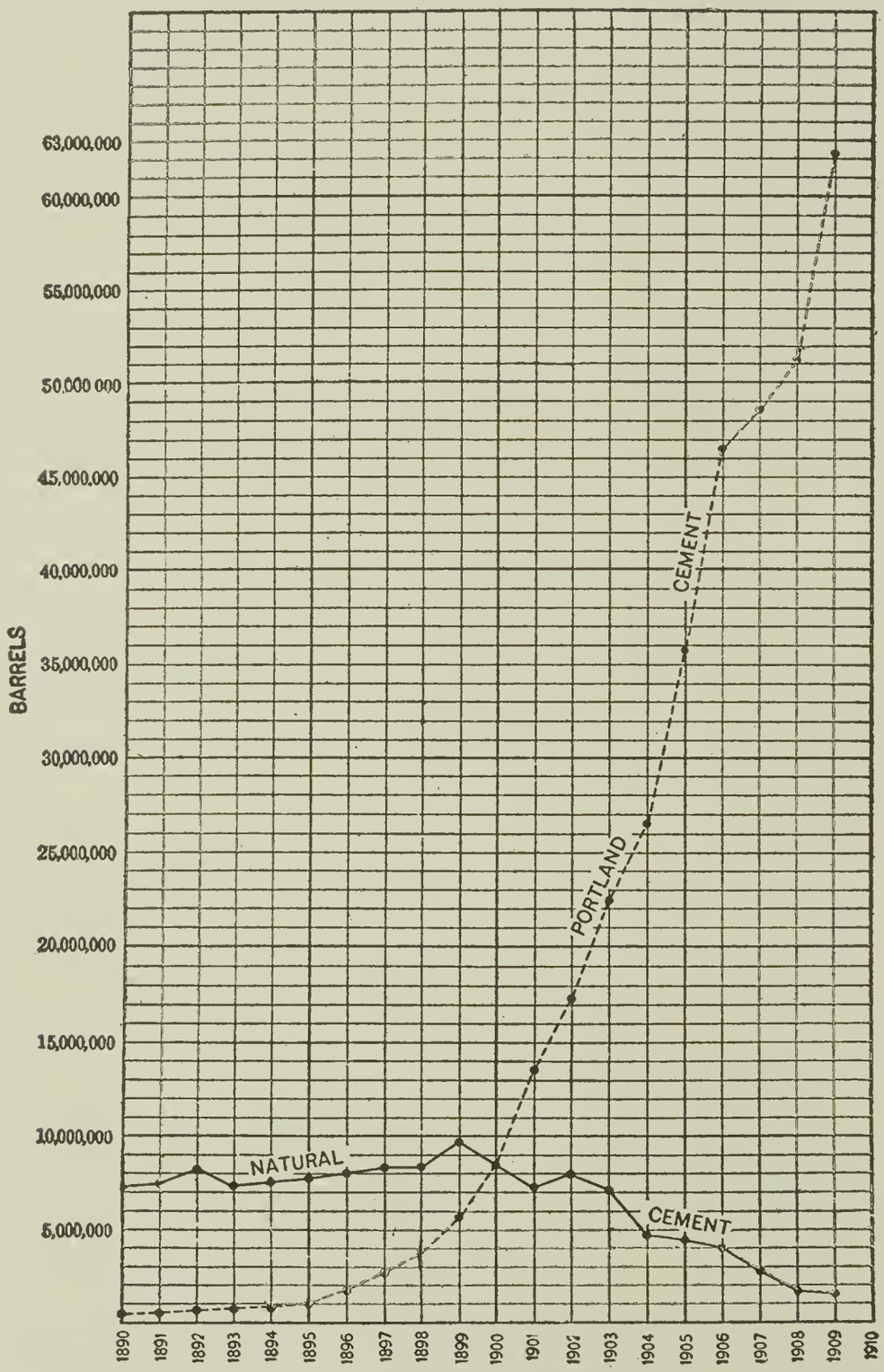

FIG. 12.—Production Curve of Portland and Natural Cement.

tions of the kiln would require only 15.7 lbs. per barrel. With reasonable losses he thinks it ought to be run with four times this amount and maybe some day in some places with something

like threefold that amount instead of sixfold, as we most often have it now.

Some are advocating dividing up the process again so that one kiln—perhaps the upright, which is so favorable in fuel economy—will be used for calcining and the more highly heated rotary for clinkering. I have known this to succeed at one plant where the works were run economically on set kilns and rotaries. This was because the company had an excellent plant of old kilns idle and at a place where anthracite culm was cheap. The prior burning of a mix of high and low limestone permitted them also to introduce the correction before entering the rotary.

I have said little of the power house and power transmission in speaking of these processes, but they have also had their natural stages of rapid evolution and improvement, as you all know. Electric driving, so much feared at first in the cement mill, has come to be universal.

By courtesy of Messrs. F. L. Smidth & Company, of Copenhagen and New York, I append sketch outlines (Figs. 9 and 10) which show a modern wet and a modern dry installation which will also give an excellent idea of the mechanical equipment and installation. It needs only the conception of the power house to complete the picture of modern cement manufacture in outline.

It is interesting now to notice from the statistics of the industry the influence of this evolutional development upon the prices of Portland cement. As pointed out by Eckel, the important epochs in the history are plainly marked in the downward curve of price (Fig. 11), and the constant improvement in the economy of production is suggested in the form of the upward curve of production (Fig. 12). It would be a very impressive reversion if a new drop in cost would be the result of studies of engineers leading to the use of water and a return to the wash-mill.

THE STUDY OF MATERIALS IN CHEMICAL ENGINEERING

Address by President McKENNA

Delivered at Niagara Falls Meeting, June 22, 1910.

EVERY one who has ever devoted himself to an inquiry into the education of a chemical engineer has noted a practical agreement amongst educators as to what studies are fundamental and necessary for such a course. Differences of opinion, where they exist, seem to prevail over the value of specialties easily acquired or over the relative order of time in taking up certain studies or the length of time to be devoted to certain others. Amongst these on which there is agreement is Strength of Materials. Naturally also there is the same as to the requirements for laboratory work for the study called Testing of Materials. So also in technology the study of important metals, minerals and valuable staples is treated of under sub-titles of each substance itself.

It has been my experience that a great advantage arises from making a review of all these subjects under a classification which brings new relations into view and avoids the cramping influence of specialization. I have attempted to aggregate and to correlate these in a manner I shall duly set forth, and to extract from these interrelations and my experience in this field certain laws which aim at making a connected and valuable study of the whole subject—theoretical, practical, economic and legal. Necessarily such a study must be called a review study. In fact, for the student, that must be its great recommendation, but it will commend itself to the teacher for many other reasons.

The rapid development of the studies whose aim is the increase of our knowledge of the substances obtained from nature by man or of fabrics composed for his use, must have caught the attention of all who have in recent years closely scanned the literature of engineering, technology or general science. It is

evident in the amount of work performed by patient and persistent investigators and reported in scientific journals. It is evident in the activity in commercial interests striving to understand better the economic value of staples that these may be produced and adopted with greater and greater profit. It is likewise evident in the grouping into national and international bodies of the growing classes of scientists who are applying the results of both former knowledge and present advancing research to the nourishment and support of a new study whose aim, while the same as that of older ones—the search for truth—is also to peer more deeply into recesses that may yield the gold of profit. This quest may have such a commercial direction, or it may have some more elevated one for man's benefit. It may assist him to new intellectual conceptions, but whether in low or in high places of scientific study the search is always for the truthfulness of the facts, laws and methods of tests which can be grouped under the title " Properties of Materials."

Now, there has been in the past a limited view of both the particular objects of study under the term " Materials," and also of the scope of the inquest to be instituted into these properties.

The elasticians began their studies upon beams and the Problem of Galileo led to consideration of compression of fibers and thus naturally to the study of columns and other forms used in construction. Naturally, the properties studied were the strength elements and the materials considered were only those used by constructors.

But a broader view of both has been brought about by two influential factors. First, the deep researches of mathematicians into the theories of elasticity have extended that study until it is seen that it is founded upon conceptions of cohesion, molecular constitution, intermolecular attractions, or other forces, and that these lead far afield amongst many other new territories of physics. Secondly, modern activities have developed engineers who busy themselves in many other branches than construction or the art of war which once monopolized their science, and who utilize as substantial agencies many other materials than wood or iron or lead.

This is a return to a better practice which was in vogue in still more ancient times, when the careful study not alone of the materials of construction but of materials of decorative use and

general utility occupied the attention of master minds. Some remarkable passages in literature, as in Pliny and Vitruvius, not to go back to the Book of Books, indicate how such results were obtained that some monuments of antiquity have survived to our time. It is probable that it is to some Babylonian savant keen enough to investigate clay and to select the best for burnt tablets that we owe the remains we have to-day of Babylonian literature.

At the present time large manufacturers are conspicuously prominent in their endeavor to bring under exact measurement every substance or article which enters into or aids the production of their output.*

I have myself been impressed by the extraordinary number of substances nowadays made the subject of inquiry by the engineer as well as the technologist. But I have been likewise impressed by the dangers which lie in the pathway of those who essay to study those materials in the haphazard fashion of an untrained observer, or to use them without any proper study of their nature.

So many are now practicing the art of testing, so many governments have established bureaus of standards, which having prepared the standards of length, mass, volume, etc., are now urged to set forth standards of composition of substances as well as strength of materials, so much encouragement is given to research in this field that it seems to go without saying that good would come from taking a bird's-eye view—shall we say an aviator's view—of present practice in this field.

Nothing can be more profitable than to review this tendency of the times, to see whither it is leading, to elicit the opinions of authorities as to how we could institute research as well as adapt better the knowledge we already have and to see if there is not more of unity and connection, more of the system and chain-like

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* Knight and Skinner (Proc. A. S. Test Mat. 1907, p. 314). "If it were feasible to present here a complete list of the different materials which form the component parts of the product of any large manufacturing company together with those which are consumed in the manufacturing processes, or of those which are used by any great railroad, the range and variety displayed would doubtless surprise those not closely connected with such work. The list for a company with which the writers are somewhat familiar contains not less than 850 items. This list is made up of definite and distinct classes or grades of materials, the various shapes and sizes of any class, all being included as one item."

advantages of a science, more of a science in one word than we have yet considered it to be.

After making this inquest I think you will all admit that the study is fully worthy of selection as a special one to be laid before pupils in chemical engineering, either in progressive stages or as a matter of review of experiences and facts coordinating what they have already learned in their courses in physics, chemistry and mechanics.

As generally understood in this connection, materials are those substances or fabrics whose applications are found in the useful arts.

If we view materials, or attempt to classify them according to origin, we find that complexity follows fast on simplicity.

We search for them of course in the earth, the sea or the air. From what is yielded by these the manufacturer or technologist obtains new material again by treatment or modification. The miner or quarryman extracts metals or stones from the earth. The oil producer obtains oils or bitumens from the same source. The fisherman brings to land tons of organic materials in the form of the bodies of the fishes which will yield oil and plant-fertilizing elements. The farmer and forester produce and reproduce from the soil or the animals bred upon it useful substances and materials in the most extraordinary variety. Few of the substances brought into commerce by these agencies are in a condition ready or fit for the uses of the principal consumers; they are usually in a crude state of unattractive association or repellant impurity, and nearly all of them must be extracted from these conditions and won into a condition of richness and purity, or must be adapted, refined and separated from the useless and unattractive substances. This is done at the hands of the metallurgist, the technologist, the refiner or the manufacturer. They call their original substance their raw material.

Raw materials are those which form the basis of the various forms of substances known in the arts. By operating upon or through those materials the manufacturer obtains the desired new substance, his Chief Product. In the performance of that operation there may be produced in addition a substance which has little relation to the substance mainly sought and for which a different outlet must be obtained in the market if additional profit is sought. Such substances are called By-Products. Some-

times no possible market or useful application can be found for them and room must be found for them as rejected matter, and in many such cases they are found to be cumbersome. They are then known as

Waste Materials. It is the aim of technology to so perfect materials and processes that there shall be no wastes and that all products be brought into such conditions or such markets that revenues can be obtained from each adequate to its importance. In the history of some industries it is therefore often noted that the waste product of former days is now almost as much sought after as the chief product, indeed in some instances has preëmpted that position. Scores of examples will occur to you.

Raw Materials are not always simply transformed—they sometimes disappear entirely during the operations they become subject to. These materials, which are mostly the products of the industries at their respective sources, and then find their applications in other industries are known as

Materials of Technical Use. They are used as aids or agents, like lubricants, cements, explosives, fertilizers; as components, like fibers in textiles, glazes in pottery, drying oils and pigments in paints; as structural elements which are the materials of construction, namely, those used to produce the rigid fabrics of engineering. Such fabrics are bridges, buildings, railways, mechanical aggregations and structures. The materials utilized are wood, stone, metals, cements, glasses, leather, paper, and a variety in minor classification. Materialogy, a term which I use because it is comprehensive and not because it is six-syllabled, therefore, can be defined as the study which deals with the properties of materials applicable in the useful arts, and with the method of testing and examining them for the determination or comparison of these properties.

The properties of materials are the attributes by which we shall know them and the characteristics by virtue of which we apply them to our uses.

Such properties as real ones and virtual ones can be here distinguished. Real properties are all those we, by common consent, recognize as belonging in the first instance to the substance itself, and by which we recognize it in both matter and form. Virtual properties are those which a material substance has by

virtue of the reaction of another material upon it. Such properties manifested by gasoline as composition, density and specific heat are real properties. The property of exploding in a closed cylinder is only a virtual one, for it cannot be manifested without the presence of air. Lubricating oil possesses in viscosity a real property, but its lubricating value, sometimes incorrectly measured by viscosity, is a virtual one, because it is affected by so many conditions requiring the functioning of other elements.

That this distinction makes for clearness and is not a mere refinement, but would play a part in vital affairs, is illustrated by the case of coal dust and flour dust, which, some would have it, can be equally classed together as explosives. But true explosives are those which contain within themselves the oxygen necessary for complete combustion; organic bodies, such as coal dust or flour dust, require air in intimate admixture before they can become explosive; it is therefore the mixture which is explosive, the particular dust being only virtually explosive. It would be, for instance, misleading to represent that nitrates of cellulose are no more explosive than wheat flour. Whether real or virtual, we recognize chemical properties, physico-chemical ones, physical ones, mechanical resistances and structure.

In chemical properties we have to consider the active and the passive properties, the ultimate chemical constitution or the proximate constitution.

Some industries find the consideration of ultimate chemical constitution of their chief materials to be of fundamental importance, as for instance in the corn industry; while others find this of no concern, but find proximate constitution to be the only one of importance, as for example, in fertilizers, rubber gum, etc.

Physico-chemical properties are seldom studied outside of the research laboratories, from which technical laboratories accept the data. Classified knowledge of this character is of primary importance for the chemical engineer. The mechanical resistances open up the wide field of the mathematics of elasticity, as well as the practical work of testing the strength of materials.

Under structure the materials would be treated of microscopically and macroscopically with regard to their morphology and state of aggregation. Few achievements of modern times in applied science have surpassed in importance the work done by this mode of study in alloys.

In the uses and applications of materials, and the traffic in them, there arise many situations wherein there is an imperative demand for the fullest obtainable information about them. This occurs not only in their use in the arts and crafts, but in disputes at law and in customs cases and patent cases, where every conceivable property of the material involved sometimes becomes the subject of diligent inquiry. Definitions can be fairly well written by the lexicographer for most of the words expressing ideas of certain materials; but definitions are only for distinguishing and not for full description. It is the full knowedge of the properties which calls for research and comparison. There is much difficulty in such a program if only on account of its immensity. If we are going to learn the most intimate properties, direct and indirect, real and virtual, of all technical substances, we must approach the subject with a peculiar mental equipment which can only be obtained by much experience; and if we are going to broaden the field thus we must seek for principles which shall supply the necessary universality, yet make for simplicity and order. There are several such principles or laws which it seems to me need only to be set down to be accepted and ratified as true results of experiences in the past.

First. The full and true value of a material for use in the arts can only be determined by ascertaining the nature of the substance or substances composing it.

This means that we will take too limited a view of a material if we consider it simply under its aspect as such and neglect to look into its basic substance. It might seem to some like a mere truism, but its importance and the waste of human effort caused by a neglect of its observance must vindicate it as something more than that.

It very often happens that the choice of an application of a material follows a very superficial study of it, and that a realization of the inappropriateness of the choice comes too late. The crumbling walls of limestone or of brownstone seen in New York City are examples of this. Other examples are found in the use of refractory clay materials. A fireclay can, on certain rough tests, be classed as refractory; a real appraisal of its value can only be made by using refined methods of chemical analysis, mineralogical, or rational analyses, extended fire tests, shrinkage tests, drying tests, etc., observations of condition, structure, etc.

Wood is only coming to be well known through a better knowledge of its basic constituents, just at the time it is beginning to disappear by reason of our wasteful methods of employing it in the past. We have been setting the torch of recklessness to the most beautiful and valuable material that nature has given us, and if she refuses her aid the art of man will never reproduce it.

Second. The simple or homogeneous substance must be the basis of study before the nature of the complex or heterogeneous can be understood.

We should know the character of iron before we presume to understand the character of iron and carbon, iron and manganese, iron and nickel, etc.

Portland cement furnishes us with an example of the applicability of this principle, because it is a very complex mixture, becoming still more complex when water is added to it. Students and theorists have wavered over it in the past, and have lately come back to the older theories of the importance of the crystallization of the lime hydrate after hydrolysis of solid solutions of metasilicate and orthosilicate of lime, and the value of the gelatinous and colloidal calcium hydrosilicate. Therefore, in this case, we should first study lime and its hydrate, then the properties of the silicates and aluminates and sulphates, their interreactions as well as those of the minerals or substances in nature having the same or analogous compositions, besides bringing to bear upon it a full comprehension of the conditions surrounding matter in the colloidal state.

Third. The economic adaptability of a material can only be determined by a knowledge of its behavior under *all* the forces inherent or applicable to it.

Tin would be an example of this, which we look upon as a firm and moderately resistent metal at all ordinary temperatures. It would be well to know, however, that if it is to be used in some very cold position it can revert to the enantiotropic form in which it has no cohesion and falls to powder. This has lately been made the basis of a detinning process.

The controversy over paint as an anti-corrosion medium on iron could be more quickly ended if there were a keener observation of this point in the tests, for in many cases the inherent properties of each coating at all its different stages of formation

should be known, and the hygroscopic condition of the plates should be uniform.

A corollary of this would be stated thus: A new and adequate point of view must be assumed in the study of an old material put to a new use. An example of this can be found in the mineral quartz which, when we were only familiar with it in its crystal form, had few properties ascribed to it as useful other than hardness, and certainly the property of elasticity or flexibility was not known to be important. Now quartz can be formed into sticks and tubes, and even drawn into slender threads, and we have come eventually to view it as a substance having valuable elastic properties and degrees of torsional resistance. Those substances which can enter the colloidal state have been put to new uses in large number, and graphite for one, thanks to Acheson, must be studied from a new point of view as almost a new substance.

Fourth. Where a series of causes operate upon a material, their effects cannot be understood until these causes are recognized and investigated, and their operation in order of time understood. I think I can make myself clear by giving the case of fireproof wood as an example. Not many years ago an investigation of fireproof wood was projected in the hope of finding a satisfactory and discriminating test, and the committee assuming charge of the matter proposed to study the different treating processes and deduce some views of testing the relative fireproofing value as well as the incidental effects of poisonous gases driven off by heat from the chemicals saturating the wood. Various ways of applying the flames to shavings and to test sticks were to be essayed. Strength tests of the wood before and after treatment were to be made and various such features were to be investigated. This investigation was never consummated, but it is probable that if it had been made according to this program much futile effort would have been spent upon it. It was early pointed out that the proper study depended upon a previous knowledge of what really goes on when wood is subjected to heat and flames. This heat can be assumed to be initially low and progressively rising. The conditions in some cases, particularly regarding the exterior surfaces, would be those normal to a free kindling of wood. The conditions as regards other portions would be those prevailing in the destructive distillation of wood without access of air. Naturally, therefore, a long series of heating and distillation tests would be

necessary, and few of the other tests of the previous program would be of any value. As a matter of fact, such a study, using a small electrically heated retort adapted for quick work, did show that the yield of gas from the heating of wood in closed vessels would make an excellent indicator of the efficacy of the fire-retarding salts used for treatment, and would not give the contradictory results of the shavings or fire test. Many complex processes in technology would become reseach problems of the first order with greater promise of positive additions to knowledge, if this principle were observed.

Fifth. Purity of substances and behavior of materials under the action of forces can be formulated in terms called Standards of Materials, but cannot be determined in individual specimens with greater exactness than the limitations of observations, of instrumental precision and of the accuracy of the available standards of measure will admit.

While this simply means that errors are personal and instrumental, it is well at times to keep it in full view and to try to know well the equations and their quantitative relations. One feature of this principle was covered by Ostwald, in what he called " the fundamental rule for drawing up a plan of measurement. The accuracy of the measurement must correspond to the exactness of the definition of the object to be measured."

A recognition of this principle also will save much useless work, because it is unfortunately too common to see enormous numbers of experiments proposed and numbers of workers engaged therein striving to use much refinement of measurement while the definition of the point involved is on a scale so much greater that no measurements will be needed other than what could be called gross measurements.

This principle also contains the germ of an idea which has often occurred to me in discussing the vexed question of standard or uniform methods of analysis. Too great an insistence upon the adoption of those methods is apt to lead away from truth rather than towards it, and apt to put a premium upon too little investigation rather than to show the danger of too great effort or waste of much time. Every substance of the same name has not the same composition, and any method which turns the chemist into a follower of system may produce economy of time in the routine of a factory and may more often than not favor comparison

of results by diverse interests; but it is conceivable that the truth can thus be missed at times, and it is quite certain that in ultimate reference more independence of method and judgment must be permitted to the experienced analyst.

Sixth. In obtaining data in mechanical resistances, the mode of application of a stress must be adequate, and the means of measurement of the strain adapted to the derivation of a factor commensurate to the magnitudes to which that factor is to be applied. In a great many branches of experimental science we can assert that what is true of the small is true of the large. This is more often observed in chemistry than in physics; it is most often physical factors which introduce variables into a problem when the results of a small operation are to be applied on a larger scale.

In pyrometry and the study of fuels we find that calorimeter test results of a coal do not coincide with results obtained on the large scale with the same coal in a boiler test.

But, in mechanics, it is particularly necessary to consider the element of variation. For example, when calculating safety factors in structures whose parts are so gigantic as to make difficult the use of coefficients by the mere multiplication of cross-sectional areas. The Quebec bridge was designed and almost completely erected upon the assumption of the correctness of certain factors for the resistance to compression obtained in laboratory tests. No data were available for computing from results obtained on large members. This was a fatal element of weakness and led to the disastrous collapse of the structure.

Out of such principles and the knowledge of properties must be developed the science of materials and the art of testing. But it must also be noted that the virtual properties consititute so large an amount of what is to be studied about materials and can form the ground for so much variety of questions to be asked by reason of the juxtaposition of one material with another, or in combination with it, or in some abnormal situation, that we must prepare a good basis to work upon. Studies of certain materials may involve applications of microscopy, lithology, metallography, chemistry, physics or mechanical forces. The measurements of science must be applied with the adequate exactitude. But it must be remembered that qualities will be as often the subject of measurement as quantities.

Clerk Maxwell has stated "all exact knowledge is founded on the comparison of one quantity with another." To be strictly true "quantity" here must include the mathematical expression of the value of a quality. Practically too the means of registering with exactitude differences of quality have not been so successful as in measuring quantities. The startling variances observable in the court room when opinion evidence is given have made this frequently evident.

We quickly recognize that he who is learned in this knowledge of materials must be a many sided man, familiar with the purposes of their production from the raw, their fabrication in the structures, their uses and exposures. He must be skilled in the applications of chemistry and physics for such investigations; his mind must be analytic; his judgment keen; his resources and resourcefulness full and ample. The experiences of hosts of observers must be collated and at his hand. This is the field of our "Bureau of Standards." Here the most learned, the most painstaking and most truth-loving devotees of the science have earned laurels for themselves and prepared the ground for their followers. There is also great work to be done by research laboratories of the universities, by those of the great corporations, and not a little aid to investigation can be rendered by commercial testing stations.

But when we come to the economic applications of testing there is a mass of misapprehension by which it is to be hoped the student will not be affected.

I think that that branch of the subject under which the materials of great works are subjected to critical tests ought to be denominated the "control of materials." It has always seemed to me that it would make for clearness if certain distinctions were observed and if certain authoritative positions were assigned to the individuals concerned in these important affairs. Thus, each of the following functions are distinct: specification, inspection, testing, judgment, sanction.

The drafting of a specification for material is the work of an engineer, an architect or technologist, making use of his experience and knowledge, or the knowledge of an authority on materials. The inspection is the routine of determining the compliance with the specification of the material being delivered; testing preliminary samples submitted from outside sources is not inspection.

Inspection involves the sampling and weighing of cargoes, determination of observable and important conditions at the time of delivery, and the transmission of samples intact to the testing laboratory. Inspection is not testing, nor is testing itself complete till the judgment is rendered as to values. Finally, this preliminary work would be useless if there could be no enforcement of the provisions of the specification. This is a *sanction* which must go by the act of acceptance or rejection, and must be within the legal definitions of the engineer's powers, as well as be susceptible of support upon referee tests. The legal aspects bear upon the responsibility of the individuals engaged in this chain of duties. The engineer specifies; the inspector reports deliveries and samples them; the testing engineer makes return of results under chemical, physical, microscopical or mechanical tests, and states the degree of compliance with the specification; the engineer accepts or rejects. If a contest ensues and it is concerned with the question of accuracy of testing methods, a referee would be chosen from another laboratory; or, if the dispute was to be carried higher, we would look upon the bureau of standards as final arbiter.

This subject could be treated for presentation to students in such a way that much groundwork as to law and contracts could be covered.

In conclusion, it will be admitted, I think, that the valuable element in this study for the young chemical engineer is the development of logical processes of thought applied in these practical fields. The great number of hours which would seem to be required for laboratory work would not be a disadvantage when it is realized that this can be coördinated in any good course in chemical and physical experimentation and the measurements of science. The student would know the chemical properties of substances in general, would be familiar with the fundamental concepts of the states of matter, but in this study he would consider substances, materials and fabrics in a scheme embracing coördinate sciences and in which the mode of attack upon the subject is always one relying upon definitions and distinctions, first principles, exactness of observation and cautious summary and judgment. If he develops to be a skilled experimenter, manipulator and mechanician he will be specially well qualified. His power of adapting his resources to his needs for determining

the factors of materialogy in any problem before him will give him the same generous equipment of self reliance that a good course in chemical analysis has given him in chemical manufacture. Any study which brings new knowledge into orderly array and reconciliation with historic knowledge, which makes insistent demands upon logical procedure, accuracy of observation and honesty of statement, and then applies results of investigation in a practical way to the most useful works of construction and production, is a fit study to place high in a course of chemical engineering.

REPORT OF COMMITTEE ON CHEMICAL ENGINEERING EDUCATION

Presented at the Niagara Falls Meeting

F. W. Frerichs, Chairman

Wm. M. Booth — F. G. Wiechmann

Geo. D. Rosengarten — A. A. L. Veillon

Circular letter No. 1 to the members of the Committee on Chemical Engineering Education of the A. I. C. E.

3828 Westminster Place, St. Louis, Mo.,
February 4, 1910.

Dear Sir: The Committee on Chemical Engineering Education was created at the Pittsburg meeting December, 1908. It was the result of a general feeling which prevailed among the members of the A. I. C. E., that the course of education generally pursued by prospective chemists at the present time does not produce men who are prepared in the best possible way for practical work in the manufacturing establishments of the United States.

As chemistry is a science which is most highly developed in Europe, and especially in Germany, it is natural that the methods of education of chemists in the United States, especially in post-graduate work, have been to a large extent copied from the methods adopted in that Continent. This is the more the case, since a large percentage of the older teachers of chemistry have been educated abroad. The highly developed chemical industries such as the coal-tar industries, the manufacture of artifical perfumes and pharmaceutical preparations, require chemists of the highest theoretical education in organic chemistry, who, at the same time are satisfied to do actuai work for long hours and for small salaries.

This condition can obtain in Europe, since there is an abundance of chemists trained for that kind of work and anxious to make a

living. This very fact enables European manufacturers to export these goods to the United States, as long as the American chemist is not sufficiently protected by tariff laws. On the other hand, many European firms support large research laboratories for the systematic development of new processes and new articles. They can do so, since the cost of experimenting and the salaries of chemists who can do research work, are comparatively low. If patents have been obtained in the United States, the goods are made abroad and imported, and the American chemist is barred from the manufacture of this class of articles.

As long as our tariff and our patent laws are not improved, there would not seem to be any hope that such goods can be made successfully in the United States.

These conditions have caused the enormous growth of organic chemical manufactures in Europe, and since a very large percentage of all the chemists find employment in this class of works, the courses at European universities seem to be shaped to suit their special requirements. For the student such a course appears to be highly acceptable, since it greatly favors organic chemistry, which branch permits of brilliant speculation, and is, therefore, most fascinating to the beginner. Besides, it coincides largely with the course which is most approved for the education of teachers of chemistry, and therefore prepares for professorships and for a large branch of a specific chemical industry at the same time.

For the universities it may be no small consideration that the students working on their theses for the degree are welcome assistants for the scientific work carried on in their laboratories.

As an excuse for this, the remark is frequently heard that every student owes it to science to devote one or two years to theoretical work, even if he does not reap direct benefit from it.

It seems natural that the scientific work, to which the individual laboratories devote their efforts, more frequently is guided by the personal liking of the professor in charge than by the earnest desire to fit the student most effectively for his chosen profession. Now the personal liking of the professors in charge would go, most probably, in the direction of organic chemistry, in which they can most easily become conspicuous, and therefore it would seem that at European universities the interests of all chemical industries not needing a specific knowledge of organic chemistry, are sacrificed to the interests of the specific organic manufactures, which have

become of so vital importance to the economic system of European countries.

But from those branches of manufacture the American chemist is largely barred, and for this reason his course of education ought to be different from that of European chemists in order to suit the requirements of his own country.

It is evident that the American student is in the same position as the European chemist entering the great variety of chemical industries other than coal-tar products, artificial perfumes, and pharmaceutical preparations. It might be well to recognize that many experienced manufacturers abroad do not consider the courses offered at European universities to be the most desirable for this class of chemists. This feeling apparently has been recognized by the authorities and has found its expression in the inauguration of the degree of Engineer Chemist at polytechnic schools in Germany.

Under these conditions, it would be of great benefit if the peculiar requirements could be pointed out, which would best fit the prospective chemist to enter practical life in the United States. An expression of opinion coming from the A. I. C. E., which embraces a large body of practical men, would seem to have a special value, and in order to crystallize this opinion into a definite form, the Committee on Chemical Engineering Education has been appointed.

It is thought that the best course for the work of this committee would be:

1st. To formulate the opinion of this committee in regard to the most suitable course of education for a "chemical engineer."

2d. To submit the opinion of the committee to the entire membership for discussion by letter.

3d. To submit the result of this discussion to a general meeting of the A. I. C. E. for final discussion and action.

If in this way the opinion of the A. I. C. E. has been formulated, it may be submitted to the institutions of learning in the United States, and the educators in these institutions might be induced to lay out courses which are likely to produce the desired results with the least outlay of time and money on the part of the prospective chemical engineers.

In order to establish the opinion of the committee on the most effective course of education, it seems necessary first to define the meaning of the term "chemical engineer."

The constitution of the A. I. C. E. in Article III, Section 1,

defines the qualifications for active membership and from these the intended meaning of the term "chemical engineer" may be inferred.

In Art. III, Sec. 1, Paragraph 1, our constitution provides for such candidates who have not had the opportunity of an early education, but who, as self-made men, have acquired by persistent work such ability in handling chemical problems as rightly entitles them to recognition as chemical engineers. The A. I. C. E. in this paragraph pledges itself to recognize the work of a true genius, independently from the way in which it has been accomplished.

The same seems to apply to candidates accepted under Paragraph 2, who have had only the opportunity to acquire the degree of B. A.

Art. III, Sec. 1, Paragraph 3, apparently indicates the course of education which is thought to produce the average "chemical engineer." But even here the definition is somewhat vague and evidently induced by the feeling that a satisfactory understanding of the term "chemical engineer" has not been established.

A civil engineer who has specialized in water and sewage purification may be a very desirable member of the Institute, and so may be the mechanical engineer who has specialized in power plant economics, and the architect who made sanitary installations a specialty. But with these branches of engineering the study of chemistry is only of secondary consideration, and for this reason a course of education would preferably be devised in every specific instance.

Somewhat different is the study of electrical engineering, since electricity is so closely allied with chemical manufacture that electro-chemistry has become a study by itself.

It would seem to be the education of the prospective chemist who is to hold the degree of B. S. in chemistry which comes under discussion by this committee, since it prepares the student for the science of chemical engineering in its more specific sense. In order to simplify the discussion, I propose to confine at the present, the work of the committee to the education of chemical engineers in this sense, leaving it to the pleasure of the committee to discuss the other branches at a later time.

In order to have a basis for discussion, I introduce the courses of a typical American university, and shall ask a number of definite

questions in order to learn the position of the members of this committee in relation to the course of "chemical engineering" offered by this university.

SYNOPSIS OF THE COURSE IN CHEMICAL ENGINEERING

Freshman Year

First Term

Subject	—Hours per Week.— Rec.	Lab., etc.
English Composition	3	
German Grammar, or	3	
French	3	
Trigonometry	5 (9 weeks)	
Algebra	5 (9 weeks)	
Chemistry (General Descriptive)	2	3
Physics	1	3
Freehand Drawing		4
Lettering		2
Total	14	12

Second Term

English	3	
German, or	3	
French	3	
Analytical Geometry	5	
Physics	1	3
Chemistry (General Descriptive)	2	3
Drawing		6
Total	14	12

Sophomore Year

First Term

German Grammar, or	3	
Reading in Modern French	3	
Differential Calculus	4	
Descriptive Geometry	3	
Sound, Heat, Optics	4	3
Qualitative Analysis		6
Machine Drawing		3
Total	14	12

Second Term

Subject	Hours per Week—Rec.	Lab., etc.
Quantitative Analysis (Gravimetric and Volumetric	1	5
Surveying	2	5
Integral Calculus	3	
Statics	3	
Optics	3	3
Assaying and Stoichiometry	1	3
Total	13	16

JUNIOR YEAR

First Term

Organic Chemistry	3	
Laboratory Organic Chemistry		6
Assaying and Stoichiometry	1	3
Quantitative Analysis (commercial and industrial products)		6
Mineralogy	2	3
Electrical Machinery	3	
Mechanics	3	
Total	12	18

Second Term

Organic Chemistry	3	
Laboratory Organic Chemistry		6
Advanced Quantitative Analysis (Commercial and Industrial Products)		6
Electrical Machinery	3	
Mineralogy	2	3
Dynamics	3	
Electrical Laboratory		3
Total	11	18

SENIOR YEAR

First Term

Advanced Quantitative Analysis (Food, Water, and Gas)		6
Physical Chemistry	1	3
Industrial Engineering	2	
Economic Geology	2	3
Engineering Materials	3	
Economics	2	
Bacteriology		6
English	1	
Total	11	18

Second Term

Subject	Hours per Week—Rec.	Hours per Week—Lab., etc.
Advanced Quantitative Analysis (Food, Water, and Gas)		6
Seminar	1	
Industrial and Engineering Chemistry	2	
Research		4
Physical Chemistry	1	3
Geodesy	1	
Economic Geology	2	3
Hydraulics	3	
Economics	2	
English	1	
Total	13	16

In the School of Engineering of this university a regular high-school education is required from entering students.

The degree of B.S. is conferred on the satisfactory completion of the four years' work.

The degree of Ph.D. is open, after not less than three years of residence and study, to all who have received the degree of B.S.

By glancing over the full engineering courses it will be found that they are arranged on very broad lines, so that specialization would not seem necessary before the junior year. At this time the student of chemistry would specialize, obtaining at the end of his four years' course the degree of B.S. in chemistry, being at this time equally well prepared for post-graduate work in pure chemistry and in chemical engineering.

If the graduate from the B.S. course desires to complete his studies in pure chemistry, or if he desires to prepare himself better for practical work, he may take a post-graduate course of three years' study and obtain the degree of Ph.D.

Having explained existing conditions as I see them, I now take the liberty of asking the following questions:

1st. Is, in your opinion, a chemist having completed a four-year course as offered at this university and possessing the degree of B.S. satisfactorily equipped to enter practical work?

2d. If question 1 is answered in the negative, can, in your opinion, a four-year course be arranged in such a way that a chemist after its completion is satisfactorily equipped to take up practical work?

3d. If questions 1 and 2 are answered in the negative, can,

in your opinion, a four-year course supplemented by one year post-graduate work taken at the same university equip a chemist to be efficient for practical work?

4th. Are the post-graduate courses as offered at American universities, in your opinion, the most effective courses which can be designed for the education of chemical engineers?

5th. If question 4 is answered in the negative, what changes are, in your opinion, necessary to make the offered courses effective?

6th. Are the courses offered at European universities and polytechnic schools, in your opinion, the most effective courses for producing chemical engineers, fit for work in American places of manufacture?

7th. Have you any specific suggestions for improving the courses, which are offered at present by American universities?

Respectfully submitted,

F. W. FRERICHS,

Chairman.

April 15, 1910

Dr. F. W. FRERICHS, Chairman, Committee on Chemical Engineering Education of the A. I. C. E., St. Louis, Mo.

My dear Doctor Frerichs:

I will give briefly my views upon the subject of chemical engineering education in answer to your circular letter of February 4.

The differences observable in the development and practice of chemistry in Europe and the United States are very well set forth in that letter, and I agree with all your suggestions upon that subject. I would add one further point of difference which, of course, springs from the same cause, and that is the larger scale of operations which we find always manifested in this country by great tonnage production. This will continue to grow as a marked feature of our work. When one understands that the genius of America is most often applied to increase of production rather than to refinement of products, it would seem to me to be a corollary from this that our students should be well trained in mechanics to meet the demand which the world seems to put upon us to supply staples. The type that we should in the future choose to imitate would be rather that of the metallurgical engineer.

In answer to your questions, I would make the following statements:

1. No.

2. Only in case the preliminary examination for entrance on the B.S. course is more severe than the present high-school graduation test.

3. Such a course as last named, with one year post-graduate course, would be adequate to properly equip a chemist.

4. Not at all.

5. More devotion to problems truly combining theory and practice.

6. No.

7. I may state my views in general as follows:

For a course in chemical engineering, the best efforts should be spent in the beginning, either in the high school or in the first year of the B.S. course. Advanced work should have been done in literature, philosophy, the nature of matter and substances, logic and mathematics and advanced algebra. The beginning of real scientific work should include most of what we have to-day in such schools as the university whose course you have quoted and might be in four years as follows:

1st year. Physics, drawing, chemistry, metallurgy, geometry.

2d year. Analysis, applied electricity, surveying, calculus.

3d year. Advanced metallurgy, mechanics, organic chemistry.

4th year. Construction, theory, and design. Materials, accounting, organic chemistry, physical chemistry, electrical chemistry.

For a doctor's degree, two years' research in metallurgy, process work, design, practical execution or economic studies.

In general, I should say, that if we could try to grasp the genius of European regard for deep study and combine it with the American genius for adaptation to any conditions, no matter how embarrassing, we would have produced a result combining the greatest strength and promise for the future.

Yours sincerely,

CHAS. F. MCKENNA.

March 3, 1910

Dr. F. W. FRERICHS, Mfg. Chemist,
3828 Westminster Place,
St. Louis, Mo.

Dear Sir: Your favor of February 5, 1910, duly received.

In accordance with your request, I herewith submit my answers to your questions, and my suggestions in the matter.

In reply to your questions:

1. No.

2. No.

3. Yes.

4. I am not sufficiently acquainted with the different post-graduate courses now offered at the American universities to form an opinion.

5. My answer to this question is implied by my answer to No. 4.

6. As far as my limited knowledge as to the courses offered at the European universities and polytechnic schools permits me to frame a reply to this question, I would state that in my opinion, the Polytechnic High School at Charlottenburg (Berlin, Germany) offers the best at the present time. The degree granted upon completion of this course is Docktor-Ingenieur.

7. My reply to this is as follows:

I would suggest that there be demanded for entrance to the university a thorough knowledge of German grammar and French grammar, and that the ability to read easy works in both languages, at sight, be required. This would permit the reading at sight in the first year of technical scientific text-books in German and in French.

I would further advise that German be thus taught in the first term of the first year and French in the second term of the first year, or vice versa, as might prove most convenient to the departments in charge.

In the second year I would also assign one term to the study of German and one term to the study of French, continuing and progressing along the lines followed in the first year, and in addition thereto, conferences on technical subjects in chemistry and physics, in these two languages.

I would also suggest adding to the first term's work, in the second year, the study of qualitative analysis and stoichiometry. In the second term of the second year I would consider it to be an advantage to omit the study of statics and to replace the same by instruction in chemical philosophy, and furthermore to complete the study of assaying in the second year.

In the third year, first term, I would replace the study of assaying, which would now have been achieved, by the study of statics and mechanics, i. e., mechanics too, if this could be arranged. If not, I would have mechanics taught in the second term of the third year.

In the fourth year, first term, I would substitute for the study of bacteriology, the course of botany 5 for botany 7, and botany 7 in the second term. In the second term of the fourth year, I would omit the study of geodesy, which I do not consider necessary for students in chemical engineering.

I have not been able to give sufficient thought to enable me to outline completely the courses of study which should be included in the post-graduate year for chemical engineers, but proceeding upon the belief that chemical engineering is essentially the adaptation of laboratory processes to factory conditions, I believe that these courses should include the study of theoretical and practical electro-chemistry, the designing and laying out of factories and the study by each student of some one industrial process along the lines in which he might be especially interested; for instance, in the manufacture of steel or of some other metallurgical process, in the manufacture and dyeing of textile fabrics, in the refining of oils, in the refining of sugar, in practical ceramics and in the manufacture of pharmaceutical products, etc., etc.

Of course, you will understand that these are merely suggestions, and can as yet be given only in a tentative way. That the proposition before us is a large one and will require a great deal of patient study, of course, I thoroughly appreciate.

With sincere regards,

Faithfully,

F. G. Wiechmann.

St. Louis, Mo., June 18, 1910.

Dr. F. W. Frerichs,
3828 Westminster Place, St. Louis, Mo.

Dear Sir: I shall try to comply with your request, to express my opinion on the subject placed before the Committee on Chemical Engineering Education by the A. I. C. E.

I have carefully read your very interesting circular letter of February 4, and will try to answer the questions therein put forth as well as it is possible for me, knowing but very little about the conditions now existing in American institutions of learning.

You ask in your letter to take as a basis for the discussion the course of chemical engineering submitted with your letter. I must confess that after having gone over the programme of the subjects given in this course, I thought that a rather unfavorable example

of chemical education in America had been chosen, having reasons to believe that the standard of chemical education of several other American universities and technical schools is by far higher than that at the university cited. On perusing the synopsis of chemical courses of this institution, I was confronted by the striking fact that the whole of the chemical education is in the hands of only three teachers, and most likely no one of the three has had any practical experience in any branch of chemical industry.

Considering the great diversity of the different branches of chemistry, it seems unlikely to me, to say the least, that effective teaching in all of these branches could be expected by such a small staff of teachers. In order to offer the opportunity to the student for thorough instruction in each one of the many courses, the combination of which constitutes a complete chemical engineering course, it seems evident that the teacher in each case should specialize in his branch. This is true of course for every line of study, but in our case more particularly so, especially for the instruction in chemical technology or industrial chemistry, where not only specialization on the part of the teacher is paramount, but where it is necessary also that his knowledge be based on practical experience.

Question No. 1.

Answer. No.

Question No. 2.

Answer. Yes and No. Four years should be a sufficient time for the education of a chemist, to make him fit to enter an industrial establishment, but all of these four years must be available for courses in chemistry and those other branches of knowledge necessary for the prospective chemical engineer. A sound general education must precede such a four years' course. This does not seem to be the practice followed in institutions such as the one whose course is quoted, where a large part of the four years are devoted to topics of general educational character. In this connection, the question naturally arises, at what age should the special training of the student for chemical engineering begin. I do not feel qualified to make recommendations in this direction, not being sufficiently acquainted with the conditions in American grammar and high schools, but I venture to say that it can hardly be expected that a young man's general education could be rounded off before the age of 19 to 20 years. At this age, however, sufficient

knowledge can have been acquired by the average student to make him fit to take up special studies.

It goes without saying that during these years of special studies opportunity must be given the student to follow courses of his own choice, not necessarily embodied in the programme of the chemical engineering course. If this is done, the danger of unilateral professionalism can be satisfactorily met.

Question No. 3.

Answer. If a four years' course is made effective, as outlined in my answer to question 2, post-graduate work should not be considered an absolute necessity, although it can but be beneficial. If, however, a four years' course comprises besides chemistry, instruction in general educational topics, a post-graduate course of at least one or two years becomes a necessity.

Agreements should exist between institutions of the same grade, which should enable the student to follow a post-graduate course in the institution which offers the best opportunities for the particular line of work which he has chosen.

Question 4.

Answer. Not being acquainted with the character of post-graduate courses offered at American institutions, I do not feel qualified to express an opinion on this question.

Question 5.

Answer. Conditional for effective post-graduate courses is a thorough preparation for such work in the form of a course of chemical engineering which in itself should equip the average student with the necessary knowledge to enter chemical industry.

Question 6.

Answer. In answering this question, I can be guided by the example of the university chosen for comparison, and in this case I consider chemists from European polytechnic institutions by far better equipped even for American manufacturing plants than chemists having followed a course such as given at this university, even if they had taken one year's post-graduate work. However, I would not like to generalize and include among the chemists with European education those who come from all European universities, for the reason that in a great many of these latter institutions very little weight is given to the technical part of the chemist's education. Still, I believe that the average chemist with the European university education will be more efficient for research

work in connection with chemical manufacturing than his brother from the American university quoted.

Question 7.

Answer. I do not feel qualified to pass criticism on the courses offered by the different American universities. I take the liberty, however, to submit a course which, in my opinion, would answer the purpose of turning out chemists ready to enter the practical field as chemical engineers. This plan is taken from the course prescribed for chemical engineers at the Swiss Polytechnic School in Zurich, and comprises $3\frac{1}{2}$ years. It should, in my opinion, be increased to four years, thus providing more time for some of the important courses which suffer by the shortness of a $3\frac{1}{2}$-year term. It must be remembered, however, that this course presupposes a thorough general education.

	Hours per Week
First Year—Winter Semester:	
Differential and Integral Calculus	7
General and Inorganic Chemistry	7
Analytical Chemistry	8
Analytical Chemical Laboratory	16
Mineralogy	5
Summer Semester:	
Physics	5
Organic Chemistry I (Aliphatic)	7
Analytical Chemical Laboratory	16
Applied Mechanics and Mechanical Engineering	7
Options:	
Petrography	3
Applied Calculus	4
Second Year—Winter Semester:	
Organic Chemistry II (Aromatic)	3
Industrial Chemistry (Water, Salt, Acid)	5
Fuel and Theory of Heat	3
Industrial Chemical Laboratory (inorganic)	16
Physics	5
Physical Laboratory	4
Applied Mechanics and Mechanical Engineering	7
Options:	
General Geology	4
Botany	2
Identification of Minerals	3
Miscroscopy L	4
Summer Semester:	
Organic Chemistry II (Aromatic)	3
Industrial Chemical Laboratory (Organic)	16
Physical Chemistry I	3
Industrial Chemistry (Alkalies, Chlorine, Phosphate)	4
Technical Analysis	5
Engineering Laboratory	4

	Hours per Week
Options:	
Bacteriology	2
Botany II	2
Microscopic II	4
Third Year—	
Industrial Chemistry (Organic), Bleaching, Dyeing, Dyes	5
Metallurgy	3
Physical Chemistry II	3
Physical Chemistry Laboratory	4
Analytical Chemical Laboratory or Industrial Chemical Laboratory	16
Gas Analysis with Laboratory	1
Machines and Apparatus I	7
Industrial Hygiene	2
Electro Chemistry	2
Options:	
Food Hygiene	1
Water Supplies	1
Bacteriological Laboratory, Elementary	4
" " Advanced	daily
Industrial Chemistry, Glass, Ceramics, Cement	3
" " principally Organic Dyestuffs	4
" " Organic Fats and Illuminants	3
Machines and Apparatus II	3
Analytical Chemical Laboratory or Industrial Chemical Laboratory	16
Explosives	1
Carbohydrates and Fermentation	2
Physical Chemistry, Advanced	2
Assaying	2
Hygiene of Heating, Ventilating, and Lighting	2
" of Removal of Offal	2
Bacteriological Laboratory, Elementary	4
Bacteriological Laboratory, Advanced	daily
Human Anatomy and Physiology	2
Organic Electro Chemistry	2
Fourth year—	
Chemical Laboratory, Advanced	daily
Political Economy	2
Options:	
Food Analysis with Laboratory	4
Paper Manufacture	2
Spinning and Weaving	2
Business Law	4
Patents	1

I am fully aware of the fact that the few suggestions offered in the foregoing are a very superficial attempt toward the final solution of the great problem now before the Institute. I am convinced, however, that a continued effort on the part of the members of the Institute will eventually bring about the desired results of

better efficiency of future generations of American chemical engineers.

Respectfully submitted,
L. VEILLON.

Dr. F. W. FRERICHS,

Dear Sir: Replying to your letter of inquiry, I would make the following suggestions:

Place at the head of the industrial chemical department a man with practical experience in chemical technology.

By correspondence and co-operation with the principal chemical concerns and the judgment and experience of educators evolve a course in industrial chemistry. This should include a course in mathematics to and including a working knowledge of the calculus, two years each of French and German, one year of mechanical drawing with especial attention to chemical machinery.

English throughout the course; *equal attention to physics and chemistry* throughout the course; one year of mineralogy and one year of economic geology.

If possible the student should be given practical work in a large chemical establishment after the Sophomore year.

The elaboration of these ideas would include the number of hours to be devoted to each feature of chemistry, physics, etc.

I do not believe in *thesis* work for the undergraduate student.

Very truly yours,
W. M. BOOTH.

From this correspondence and from oral discussions with members of the committee, it would seem that in their opinion even a successful four years' course at one of our good universities following a regular high-school education is not sufficient to equip a student of chemistry satisfactorily to enter practical work.

As to the remedy, the opinions are divided, since it is proposed to require either a more advanced education in chemistry in the high schools or else post-graduate work after completion of the regular college course.

It seems to be the consensus of opinion that the post-graduate courses as offered now at American and many European universities are open to improvement if it is desired to fit post-graduate students for efficient research work in the chemical industries of the United States. In offering the subject for discussion in this meet-

ing, it would seem to be of importance to bear in mind that the field of chemistry at the present day comprises specific knowledge in an almost infinite number of directions, and that in order to be successful it would seem to be imperative for a chemist to specialize and to concentrate his efforts on a small but well-defined part of the almost endless field of chemical research. This would not exclude the prospective manufacturing chemist from having a good general knowledge of the elements which form the basis of chemical engineering. On the contrary, he should have a good general knowledge of inorganic and organic chemistry and of physics and he should have perfectly assimilated these subjects so that it comes easy for him to think in terms of these sciences.

By making a large number of preparations he should have familiarized himself with the properties of the elements and their compounds, and should have a good knowledge of the methods of separating chemical compounds from mixtures and of the production of pure chemicals. Particularly should he be an expert in chemical analysis, even to that extent that he could criticise existing methods, devise new ones to fit new conditions, and he should be able to control the reliability of methods and to ascertain their limit of accuracy.

The graduate student should have a fair knowledge in advanced mathematics and its application, and be well trained in the drawing of machinery and structures.

He should have had manual training and be able to handle tools of the more important trades. His knowledge in languages should be such that he can read with ease professional publications in French and German languages and express himself clearly in English.

These studies, if pursued properly, would seem to fill an entire four years' course, and before they have been assimilated advanced work would seem to be of little benefit.

A chemist thus prepared may go into practice, but he leaves it to chance whether his progress will be rapid or slow. There may be instances where an intelligent manufacturer will lead him to apply his faculties to promising problems, but in most cases the first years will be wasted in futile efforts and costly experiments.

Quicker, certainly, and less costly experience in applying accumulated knowledge could be obtained by post-graduate work under the direction of good teachers at a well-equipped institution.

But these institutions must be fitted to suit the particular requirements of American chemical industries, and the courses must be directed by teachers who are entirely at home among domestic manufacturing methods.

It has been pointed out by one member of your committee that the Polytechnic School of Zurich, Switzerland, has been particularly favored by having had for a long period of years two teachers, viz., Gnehm and Lunge, the former a successful manufacturer of coal-tar preparations, the other an expert in the soda industries, both of whom taught at the same time and were constantly in close contact with their respective industries.

Unfortunately it would seem impossible to duplicate these conditions in the United States. Expression has been given to the thought that no university could tempt a successful manufacturer in the United States to take up teaching, even if he had the ability to do so, and the average professor of industrial chemistry would hardly have the opportunity to obtain a full insight into the actual conditions of the chemical industries. What is published in handbooks of industrial chemistry to a large extent is hearsay and antiquated, and it is only natural that manufacturers are loath to divulge their experience for publication. The consequence is that the collecting and reporting professor of industrial chemistry is often teaching methods and processes long since abandoned and replaced by better ones.

What we must have for post-graduate work are producing teachers of industrial chemistry who, like Lunge, work ahead and do not follow the progress of the technical industries. Men of this kind will have information to offer to the manufacturers and in turn will obtain information upon which they are able to base the progress of their work.

To the places where such men teach, post-graduate students will flock and will be willing assistants for the work of their laboratories.

Some of the studies which might be taken up to advantage in a post-graduate course for chemical engineers are the following:

1. Exercises in making chemical preparations quantitatively—that means the making of chemical preparations, observing weights of raw materials used, time of reaction, concentration, pressures and temperatures most favorable for the production of chemical compounds, and the yield obtained. These excercises should be

carried on in great variety and with great exactness, since they form the basis of most research work in chemical engineering.

2. Study of materials of construction for chemical apparatus, including metals, alloys, stoneware, cement, rubber, protal, wood, and others. These materials should be studied, not only with reference to strain and workability, but also with reference to action of various chemicals upon the materials.

3. Study of construction of machinery and apparatus. This should include a study of the limitation of materials in their application for making apparatus and also the preservation of apparatus from destructive influences.

4. Measuring apparatus and methods of measuring.

5. Study of the generation of steam: types of boilers and boiler furnaces, boiler feed water, purification of same, fuels, methods of making tests for efficiency, firing with coal, oil or gas, calculation of cost.

6. Water supply.

7. Study of generation of power, steam engine, water wheels, electric motors, transmission of power.

8. Construction of furnaces, pyrometry, materials for furnaces, construction, repairing same, construction of chimneys, fuels for furnaces, efficiency, calculation of cost.

9. Study of evaporation of liquids and solutions under high pressure, under atmospheric pressure and *in vacuo*, concentrating solutions, calculation of cost.

10. Construction of drying plants, theory of drying, drying *in vacuo*, collecting evaporated solvents.

11. Theory of distillation and construction of stills, rectification, dephlegmation condensation.

12. Theory of saturation, extraction, and absorption.

13. Study of evaporation of solids, resublimation.

14. Theory of crystallization, crystallization in motion and *in vacuo*.

15. Methods of treating solids with liquids.
Methods of treating solids with gases.
Methods of treating liquids with gases.

16. Methods for purifying solids, liquids, or gases.

17. Grinding and disintegration machinery, separating and mixing machinery.

18. Handling of solids in large quantities.

Handling of liquids in large quantities.
Handling of gases in large quantities.
19. Buildings and structures for chemical plants.
20. Packages and materials for same.
21. Handling and disposition of labor and prevention of accidents.
Liability insurance.
Accident insurance.
Regulation of wages.
22. Sampling and testing chemicals.
23. Controlling the manufacture by logs.
Factory bookkeeping and calculations.
24. Patent law, tariff law, corporation law, contracting.
25. Discussion of special industries.

It is true, many practical problems *cannot* be carried out in a laboratory on a small scale, and therefore *cannot* be an object of study in a post-graduate course. But a very great number of processes *can* be worked out in the laboratory and it would seem that in connection with these the theoretical part of industrial chemistry could be worked out in a satisfactory manner. In order to do this there must be at least one teacher of industrial chemistry and at least one institute which will carry out the work.

Our friend, Dr. Baekeland, said recently in his address at Pittsburg, that the principal object in a research laboratory is the research chemist himself. I guess he is right. But it is believed that it will be a long time before the universities without the assistance of practical manufacturers can produce such a man. In my opinion, the A. I. C. E. could be of great assistance in bringing this about. If a university of high standing would undertake to establish a post-graduate course for chemical engineering, the A. I. C. E. might offer the assistance of a committee from among its members, to act in a consulting capacity to the faculty and to help in this manner, to originate an efficient course. But it would seem necessary that the professor of industrial chemistry to whom the work of post-graduate students is entrusted devote his entire time to this work and be not burdened with work in undergraduate departments. He should have a well-equipped laboratory and a staff of the best assistants at his disposal, since the field of research is large and the detail work, particularly in the beginning, would seem overwhelming. As to the duration of such a course, it is thought that two years are sufficient

if only well-prepared students are entered. Upon the termination, an appropriate degree might be conferred which no doubt would be highly treasured by the possessor.

Committee on Chemical Engineering Education,
F. W. Frerichs,
Chairman.

Discussion.

President McKenna:

This painstaking and valuable report will be printed in a Bulletin in anticipation of the regular Transactions. The members of the Institute will be asked to send to the Secretary their opinions on this subject. These will be edited by the Committee on Chemical Engineering Education, and will, together with this report, form the basis of a progress report at least at the annual meeting. If there is anything of importance that members wish to put forward at this time—some important view—it would be well, of course, for us to have it.

Secretary Olsen

I feel in the first place that the Institute is undertaking a very important work. I am ready to admit that the conditions in American colleges and American universities are in many cases deplorable. I think there is no question of it. There are certain influences at work at present to improve and change those conditions, and I am glad to see this Institute entering the field. There are too many colleges in the country poorly equipped and with very little endowment. Why, in one State they passed a law that a college should not grant degrees unless they had an endowment. The law as at first proposed was that that endowment should be—half a million? No, $25,000 was enough to make a college! After the legislators had discussed the matter, they decided that it was too high, and brought it down to $5000. As Dr. Butrick has said, any preacher can give his note for $5000, and establish a college and give degrees. I say that public opinion should stamp out such institutions, and place American education on as good a basis as American industries generally are, and root out a lot of those poorly equipped institutions which are in the field giving degrees.

After having said that, and saying that we ought to educate public sentiment for thorough, sound, and broad education (and

we can begin a lot lower than Dr. Frerichs has suggested and do good work), I want to say a few words with reference to the typical courses which have been given. You will have noticed the great difference between the three propositions. The last one, giving the course at Zurich, included a long list of technical subjects covering all branches of applied chemistry. That was in Europe. The other suggestions are much simpler. Our practice differs from that in European countries in education, as well as in industry. When American capitalists have built a railroad through the country, they have in many cases thrown the ties down on the bare ground, spiked down the rails and started running trains. That's cheap construction. After they have constructed it in that way they begin to gather in the earnings. Then they proceed to raise the track here, place a bridge there, straighten the track and put in ballast, and to improve the equipment, and after a few years, using the earnings, the road will be in pretty fair condition. In Europe how do they do it? Their capitalization per mile is very heavy, because they build a railroad complete in the beginning. Now the education given in that course at Zurich was designed to be complete right at the start; it is supposed to turn out a man who knows all about vacuum drying right from the school. We do not do that in America. How do we do? In America we say, give a man a broad, general education, give him the principles of his science, drill him until he knows the broad fundamental principles, and then, if he goes into Dr. Frerichs' laboratory, he will soon learn how to distill ammonia. We trust him to pick things up as he goes along, and go upon the plan of not giving specialties in college. I received my technical training at the Johns Hopkins University. They said: "We will not teach qualitative analysis very thoroughly; we will teach you the properties of chromium until you know chromium—know it so that you could find it under any and all conditions." So we in America have gone at the problem of education from that standpoint. Give the students a broad general training in the principles of the sciences—theory, if you choose to call it so. We have said that if he has the principles of chemistry and engineering, if he has his mathematics, his German, and his French, so that he can read the literature, he will get the applications. Now the question is, is that the right principle to start out on? I would like an expression of opinion of this Institute as to whether that is the way to proceed.

Mr. Baker:

I do not want to throw cold water on any steps which may be taken to turn out industrial chemists, but I do not think it is possible to turn out a full-flegded industrial chemist. The conditions in the factory are entirely different, if not diametrically opposite to those in the laboratory. In the laboratory the work is done under ideal conditions, and the least important factor is economy. In the industrial plant the most important factor is the economical one, because an industrial plant is run to make money and not to demonstrate a chemical theory. Another important factor is that of the physical conditions he must contend with, and does not meet in the laboratory—the "cussedness of inanimate things"—I do not know a better way in which to express it. Someone has aptly said that to gain an education is to cultivate an attitude of mind, which I take to mean, to learn how to look at things. The best chemist is not the man who works all hours of the day working out a problem given in a book, nor a man who burns the midnight oil, but the man who looks into things—the man of an investigative turn of mind—the one whom you would term a crank—one with the spirit of the boy who cut the head of the drum to find out what made the noise.

President McKenna:

The Institution named in the committee's report was taken only by chance, and, if we were to take the statements made and opinions expressed upon the course in that institution too literally, it would appear as if it were very unfairly treated. That is not the meaning, I feel sure, of such an inquiry. It was referred to only as a typical institution of medium grade.

CIRCULAR LETTER TO THE MEMBERS OF THE A. I. C. E.

The A. I. C. E., in semiannual convention assembled, has received the report of the Committee on Chemical Engineering Education, which is printed in full in this Bulletin. It was the expressed desire of those present that the leading questions be put to the entire membership for a letter vote. To simplify matters the seven questions asked in the report are condensed into two, and upon the answers received to these questions the further work of the committee will depend.

The entire movement has grown out of the general feeling that the present courses of education are inadequate. To investigate whether the feeling has a valid foundation the committee has been appointed and the object of Circular Letter I has been to ascertain the individual opinions of the members of the committee.

The answers have been singularly unanimous, and it would seem to be the established opinion of the committee that a change in the course of chemical engineering education is imperative for the welfare of the profession. In order to bring this about we must induce the universities to adopt new courses. The influence of our committee would seem to be insufficient to bring about so radical a change unless it is backed by the concurring opinion of an overwhelming majority of our members. In fact the backing should be unanimous and to obtain such support this vote is taken.

The question rests before the Institute whether a four-years' course as offered by the average American university following an ordinary high-school education is sufficient to produce chemical engineers satisfactorily equipped for important practical work in American manufacturing.

The opinion of the committee seems to be that it is not. If an overwhelming majority of our members is of the same opinion we may work for a reorganization with some hope of success and may negotiate with the universities for the establishment of a better course.

The questions which you are earnestly requested to answer are as follows:

1. Is, in your opinion, a four-years' course as offered by the average American university, following an ordinary high-school education, sufficient to produce chemical engineers satisfactorily equipped for important practical work in American industries?

2. Have you any specific suggestions for improving the courses which are offered at present by American universities?

You are invited to answer this question in considerable detail.

REPORT OF THE COMMITTEE ON CHEMICAL ENGINEERING EDUCATION

Read at the New York Meeting, Dec. 7, 1910.

THE Committee on Chemical Engineering Education is pleased to report material progress in its work.

What was presented in the meeting at Niagara Falls was published in the Bulletin of August, 1910, and was given a very wide publicity by being reprinted in *The Journal of Industrial and Engineering Chemistry*. The subject has obtained widespread attention, and no doubt many of our members will now be ready to take part in a profitable discussion. For this reason the first session of our annual meeting with the exception of one paper is devoted to this subject, and we are fortunate in having among us Dr. F. W. Atkinson, President of the Brooklyn Polytechnic Institute, and Professor M. C. Whitaker, of Columbia University, both of whom have kindly consented to give us their views.

First of all, however, I would like to correct two errors in the last report to which attention has been called by Professor Lunge, in Zurich. On page 29 of the Bulletin reference is made to the University of Zurich, while it should be the Federal Polytechnic School of Zurich at which Professors Lunge and Gnehm are teachers. The second mistake is on the same page, where the name of Gnehm erroneously is printed Guckum. While I plead guilty to the first mistake, the printer is responsible for misprinting the name of Gnehm.

A number of communications have been received which bear on the subject.

Dr. O. Zwingenberger expresses his interest in the movement, and more particularly sides with the position taken by Mr. F. G. Wiechmann. He calls attention to the course given at the Technische Hochschule in Dresden, Germany, where the Chemical Department is directed very successfully by Geheimrath Professor Dr. Hempel, who is well known to you all by his remarkable work in gas analysis.

Professor Horace G. Byers, Director of the Department of Chemistry at the University of Washington in Seattle, writes his approval.

Dr. William D. Richardson, editor of the *Journal of Industrial and Engineering Chemistry*, sides with the views taken by Dr. L. Veillon, and expresses the opinion that the main difficulties with post-graduate courses are, that they are not under the supervision of men with practical industrial experience. It is difficult, he says, to secure good teachers who are at the same time posted in manufacturing lines, or good manufacturers who are also good teachers. Possibly, he concludes, the committee from the A. I. C. E. in co-operation with the section on Chemical Education of the American Chemical Society would be able to devise a suitable plan.

Finally, there is a letter from Dr. William M. Grosvenor which would seem to contain so many valuable suggestions that it forms a paper in itself. For this reason I would suggest that it be read in full:

September 12, 1910.

Dr. F. W. Frerichs,
3828 Westminster Place, St. Louis, Mo.

My Dear Doctor:

Pursuant to the request contained in circular letter at the end of our August Bulletin, my reply to question No. 1 would be emphatically no.

Question No. 2, yes, and more specifically would suggest that the training be modified in order to teach the young men how themselves to utilize their own brains and the known facts instead of devoting so much effort to teaching them what other men have done with their brains and the effort to acquaint them with all the unknown facts.

At the present the nearest approach to what seems to me the desirable method is in use at Pratt Institute. The plant, however, is in miniature—perhaps too much so. An interesting attempt on a larger scale with the active co-operation of manufacturers and outside experts is being considered at Columbia, initiated by one of our own members. This is, it seems to me, the only way to make academic training entirely safe and altogether valuable technically.

I say entirely safe, because from my own experience I can testify that the academic training is to a large extent valueless,

and the academic habit of mind is distinctly dangerous in technical work. With all our admiration for science and theory, an honest canvass of industrial history will show that 99 per cent of the valuable discoveries and improvements have been based on more or less ignorant empirical effort. The one most valuable fruit of my academic years was a scholastic heresy drilled into all his students by a man who was head of the chemical department and is practically also the head of one of our largest universities. When we went to him as students with an idea, a theory, a plan of attack in our work, he would look us straight in the eyes, smile quizzically and say "try it." The character of courses at present permitted by academic standards and the facilities available for academic training, are very poorly adapted "to trying it." The mental attitude which approaches a technical difficulty with the desire to know what other men have done and to find a satisfactory theory before proceeding to meet the difficulties, is a dangerous one. It is productive of too much hesitation and delay for practical success. The scholastic attitude of mind leads us to regard theory as a profitable guide to action or method. Practically it is valuable almost wholly for interpretation of results obtained. Theory is far more useful in explaining failure than in pointing the road to success.

Therefore I would model academic courses intended to fit men for practical work upon the lines which have given Germany the pre-eminence in theoretical work. Give the man his problem, his materials, his sources of information, and leave him to do the rest, criticising the work as much as possible, suggesting methods as little as possible. This is the method pursued in German Universities, where men are trained to pioneer work in theoretical investigation, and such training has resulted in an independence, aggressiveness, patience and exhaustiveness which has placed Germany at the head of theoretical chemical knowledge. The same method is employed to a less extent in her efforts at technical training, and in opening up new industries as well as making radical improvements of old industries, Germany is setting the pace for the world. We are pressing her closely in many directions because there are among us so many men in control of industries who have received their education on a large scale in the plants by precisely similar methods practically applied. In almost every instance we have excelled her in the magnitude and gross perfection of our method for this reason, whereas she has

excelled us in the refinement and quality of her results because the training of her men has been broader and more thorough than is possible to the practical man with the daily demand of tonnage driving him into the earliest possible execution of any improvement he might devise.

Another point wherein academic education both in Germany and in this country may be said to widely miss the mark is very difficult to express. It is perhaps more a question of character training than mental training. It is a matter in which our universities do better perhaps than the German universities, but by no means as well as could easily be done. This is the question of giving young men the optimistic courage that comes with experience. To a certain extent some of our universities in their college work give young men a great deal of this in athletics. The spirit of the West has given it to a great many more. Wits are worth more than knowledge technically. The young man who had the wit to dump half a barrel of broken stone and a barrel of china clay into a 200,000-pound tank of mixed acid (at 3 cents a pound), when it sprung a leak, saved more by wits in a few minutes than his knowledge was likely to save in months. The young engineer who substituted "and" for "or" in a mining contract which called for the conserving of paint rock or low-grade ore, had his wits about him and saved his lessors more money than he will probably ever be paid in salary in all his life. It seems to me that too much effort is devoted in the schools to training the mind in a philosophical way and too little in training what we are to call the wits (what are probably really the senses and the mental perceptives).

I inclose a curriculum of a chemical engineering course (A*) which seems to me better adapted than the curriculum cited. This course demands higher entrance requirements, but I think that this will be necessary. Another course, marked (B†), seems to me much more desirable. It will be noticed that the final degree is given not merely for scholastic work, but for undergraduate scholastic work followed by practical graduate work including a thesis requiring investigation and also requiring the satisfactory performance of technical work as an employee. But after all it seems

* Chemical Engineering Course of the Polytechnic Institute of Brooklyn.

† Chemical Engineering Course of the Towne Scientific School of the University of Pennsylvania.

to me much more largely a question of the manner and spirit in which training is given, because the value of the training is, after all, the effect on the student's mind, and he may be trained throughout the entire course to make quick, practical application of what he knows, to seek facts simply and empirically by the shortest possible route, keen perception in the study of men, and the application of his wits to the pursuit of success through failure. Or with precisely the same curriculum he may be trained to theorize, to hesitate, to strive for knowledge rather than results, and allow his thoughts to become "ingrowing," studying his problem in the limited sense instead of studying the game, losing his perspective and sacrificing the real ultimate prize for which he is working.

Unquestionably one reason for this tendency in scholastic circles is because the type of men largely devoted at present to the education of young men is a type eminently scholastic. A remedy should be found in the securing of successful practical men to present as large a portion of the courses as is feasible. The courses of education might lose coherence thereby and the men might not be as skillful teachers as professional teachers; but the whole object of teaching chemical engineering is not to impart knowledge. It is to develop ability, and the practical man can at least present an example. Furthermore, he is as a rule a past-master in the study of men and the development of efficiency in human machinery. To make successful chemical engineers we must apply some of the time now given to making philosophers to making efficient machinery for the elaboration of men, commercial conditions, material and machinery into money. These complicated machines must still be to some extent philosophers, but the point is they are gauged not by the profundity of their argument, the breadth of their knowledge or the acumen of their theory, but they are judged like machines on the delivery of goods.

Very truly yours,

(Signed) WM. M. GROSVENOR.

Respectively submitted,

The Committee on Chemical Engineering Education,

F. W. FRERICHS,

Chairman.

REMARKS ON CHEMICAL ENGINEERING EDUCATION

By F. W. FRERICHS

BEFORE opening the discussion on the report of Chemical Education, I would like to recall to your memory some of the principles which might govern the studies of young men, possessing a high-school education for the profession of chemical engineers.

With the object in view to make the student self-supporting after completion of a four years' course, and at the same time to prepare him for post-graduate work, his efforts might be led in three directions, viz.;

1st. His general education might be extended, particular attention being given to English, German and French languages, to mathematics and physics. This would enhance the general training of his mind and would prepare him for the more specific study of chemistry and chemical engineering.

2d. A good general knowledge of inorganic and organic chemistry, including the making of chemical preparations, might be acquired, and a most thorough training in analysis. This would fit the young chemist for usefulness as an analytical chemist immediately after graduation from a four years' course.

3d. Advanced mathematics with application to chemical problems and mechanical drawing of structures and chemical apparatus would prepare the student for post-graduate work in chemical engineering.

These subjects, in my opinion, would fill a four years' course, would make the student a useful analytical chemist, would make him self-supporting upon his graduation and at the same time would prepare him for advanced work in chemical engineering.

A thorough training in drawing and analysis would seem to be of the greatest importance and almost indispensable for the young chemist at the time when he is looking for first employment in the industries. The manufacturer employs chemists for profit

and not for the sake of humanity. Analysis and drawing are the only two arts in which the young chemist can be proficient at graduation, and at the same time the manufacturer is often desirous of being relieved of this kind of work in order to obtain an opportunity for making use of his experience. If an applicant for a position is not master of these arts, he probably will find that there is no place for his talents.

This would seem to apply equally well to chemical engineers who have had the opportunity of doing post-graduate work. Wherever a chemical engineer may find first employment, his first useful work is likely to be in the line of drawing and analysis. But if he is proficient in these arts, if he has also mastered advanced studies in chemical engineering and has his wits about him to find the defects of a plant, his advancement to better positions will be rapid and sure to come.

Chemical engineering is closely related to mining and metallurgy, arts in which America has admittedly excelled all other countries.

I shall never forget a day which I had the privilege of spending about eight years ago in the School of Mines at Golden, Colo., when its president, Mr. Regis Chauvenet, conducted me through the departments.

The drawings made by the students were works of art and models of correctness, and nothing but hundred per cent would pass at any time during the four years' course.

Assaying and mineralogy were mastered to perfection.

Every place at this school was filled, and there was a waiting list of prospective students. If a young man failed to keep up with his class he was not permitted to take the course over again, but had to make room for a worthier student. But a diploma earned by a four years' course at this school gave to the fortunate possessor preference to others, and every graduate would have a choice place at $125 a month to begin his practical career.

If we had graduate chemists with a good general education, similarly trained in the elements of chemistry, in analysis and drawing, and if we could give to them an opportunity of becoming chemical engineers by doing post-graduate work in chemical engineering at a well-equipped university, we could have perfect plants containing perfect apparatus and conducted with high economy which might favorably compare with the most highly developed mining and reduction plants of the United States.

THE DEVELOPMENT OF THE CHEMIST AS AN ENGINEER

By Dr. FRED. W. ATKINSON, President of the Polytechnic Institute of Brooklyn

Read at the New York Meeting, Dec. 7, 1910.

THE comprehensive circular letter No. 1, to the members of the Committee on Chemical Engineering Education of the American Institute of Chemical Engineers presents clearly and concretely a problem of vital importance to the engineering educator as well as to the manufacturing chemist. The subject is, indeed, one to which little explicit attention, outside the colleges, has been paid. In any attempt to formulate a definite and practicable programme for the training of chemical engineers this society will be obliged in a certain sense to beat out its own path. The situation regarding such training is still chaotic and the technical institutions are by no means agreed among themselves as to the most suitable course of education for a chemical engineer. They will welcome heartily a report from this body of practical men which will point out the causes, results, and deficiences, of the present method of training and which will suggest courses likely to produce better results.

I note from my examination of the membership cards of this association that a wide diversity of data is displayed under the headings: "Present Occupation and Business Connection," "History and Education," and "Career in Chemical Engineering." I should infer from the facts exhibited on these membership cards that very few of the members of this Institute have had any formal training in engineering subjects and that what they had achieved as chemical engineers was due entirely to their own individual development in response to the practical demands made upon them as chemists. Many of them bear the stamp, like many another excellent product, "made in Germany," which

implies that they brought to their profession a knowledge of the modern advance in chemistry and an appreciation of investigation. If I as an outsider may presume to make a suggestion, it would be that *every member of this Institute* be given an opportunity to express his opinion with reference to the course in chemical engineering which will produce graduates who shall be so trained as to meet the requirements of the chemical industries in America. In any expression of views upon the general subject, it is important to keep in mind that in technical schools it is not feasible to assign more than 15 hours of lecture or recitation, and 15 hours of laboratory work per week for four years, or, at the most, for five years. A larger weekly assignment only results in poor preparation, giving a smaller net return in training and acquisition of knowledge.

It should also be clearly recognized that it may be impossible to develop in the technical school or the engineering department of the university qualities or ability which are very necessary in the factory, and that a portion of the education or training of the chemical engineer must always be obtained during a period of apprenticeship in chemical works. High proficiency in chemical engineering can never be reached without natural ability and long experience. The chemical engineer forms no exception to the law that experience is an imperative necessity for every human being. A college can no more turn out completely developed and efficient chemical engineers ready for positions involving superintendence and responsibility than it can produce lawyers and doctors expert at the day of their graduation.

After the views of the members have been obtained and the consensus of opinion of this Institute has been formulated (which will be no easy task), I suggest as perhaps the best method of approaching the educational institutions that the final report with definite recommendations be submitted to the Society for the Promotion of Engineering Education for consideration by its members, most of whom are engaged in college instruction. A joint meeting of the two societies might also be arranged, for if this problem is ever to be solved successfully it will be by bringing the chemical manufacturers and the college instructors in more intimate and more co-operative relations.

As a result of a popular demand by far the larger number of our colleges are attempting in a four-year course, to provide the

instruction required by the prospective chemical engineer. This is too short a course. The chemical engineer is a combination of the chemist and the engineer, and I believe it is the fundamental mistake of the colleges that they do not insist upon at least five years for the completion of a course in chemical engineering. A five-year requirement is bound to come and should this Institute reach the conclusion that the usual period of four years is too brief for an adequate preparation, I believe its recommendation to extend the time will have great weight with the educational authorities, and will tend to accelerate the movement in the direction of a more suitable training.

In either a four- or a five-year course the proportion of time devoted to chemical subjects should exceed that given to engineering subjects. As a primary requisite the chemical engineer must possess a broad, comprehensive knowledge of chemistry, theoretical and applied. Although I have no doubt but that some of you may disagree with me, yet realizing as I do the practical conditions governing college instruction it is my opinion that this chemical training must necessarily be general and fundamental rather than specialized. Instruction in chemistry should continue through the whole length of the course. The freshman year of such a course will be identical with that offered to prospective chemists and very similar to that pursued by engineering students. English, French, or German, mathematics, physics, drawing, and general descriptive chemistry are the usual subjects of the first year. We find at the Polytechnic Institute that about thirty per cent of the students are able at the time of entering to pass examinations in trigonometry and higher algebra, and in chemistry. Such students are able at once to take up more advanced work in mathematics, and to begin their qualitative analysis in the freshman year. In the second year, English, modern language, and physics, should be continued; some period of history should be studied; and in mathematics, the calculus should be undertaken. Qualitative analysis should perhaps come the first and quantitative analysis the second half year. With the exception of the introduction of the calculus the second year of the five-year chemical engineering course of the Polytechnic differs but little from the second year of its chemical course. In the excellent four-year chemical engineering course of the Massachusetts Institute of Technology, I note that the engineering subjects

of mechanism and mechanical engineering drawing are introduced in the second year. The subjects machine drawing and surveying appear in the second year of the course printed in circular letter No. 1 to members of the Committee on Chemical Engineering.

This difference of practice in the time of introduction and in the character of engineering subjects becomes greatly accentuated in the third and fourth years of the courses offered by our American educational institutions. It may safely be said that no two institutions have from among an almost bewildering variety of engineering subjects made even approximately the same selections. Local conditions will, of course, always be one of the determining factors in the shaping of these courses, and a free rather than a standardized development of professional courses is the usual American educational experience. Nevertheless, I believe that greater care in the selection of engineering subjects based on actual experience which the members of this Institute can furnish is both desirable and possible. The hopefulness of the situation lies in the fact that the members of this Institute have undertaken this study and are in a position to indicate to the college authorities just what changes in the present courses are necessary to bring about the desired results. Chemical engineering needs to be more sharply defined. Its scope is still in a somewhat indeterminate state and as yet its position as one of the professions is not clearly recognized.

The present courses are founded on the assumption that the chemical engineer must, beside being a chemist, also be something of a mechanical engineer, and to a less degree something of an electrical engineer. It is further assumed that the chemical engineer will not be expected to show results so much as an analytical chemist or as a student of special research who spends his time in the laboratory of the manufacturing plant, but as a managing chemist who remains in the laboratory only long enough to get his business bearings. Broad expert knowledge and an inventive ability combined with a natural aptitude for administration and management are the principal characteristics of the successful chemical engineer. I should like to know if these assumptions are true, for if they are it is at once evident that the training for such a profession must be broadly fundamental rather than narrowly specialized.

The colleges are pretty well agreed upon what shall be done

in the fundamental branches of mathematics and physics. Solid geometry, advanced algebra, trigonometry, descriptive geometry, and the calculus are the mathematical subjects taught, and the physics course of two years' duration is mainly devoted to the subjects of mechanics, light, heat, and electricity. English is sometimes limited to the work in the preparatory school, but as a rule it is taught for one year, and often for two years, which is none too long a time. It is of the highest importance that the chemical engineer be able to express himself clearly and concisely. Economics is becoming recognized as a desirable and necessary subject for all engineers. The other general subjects to be included, such as history, logic, and business law, depend upon the length of the course—whether it is four or five years' course. The colleges are further agreed that mechanical engineering drawing should be included and that there should also be thorough fundamental courses in mechanism, applied mechanics and thermodynamics.

There are many points upon which the colleges are not agreed, and a few of the more important of these I am presenting in the form of questions to the members of this Institute.

1. Are both French and German essential to the chemical engineer?

2. Of what should the course in applied or technical chemistry consist? Specify the subjects to be taken and the proficiency to be acquired in each.

3. How much investigation should be required and of what character?

4. Beside mechanism, applied mechanics and thermodynamics what mechanical engineering subjects should be included? Steam engineering? Machine design? Steam power plants? Gas power? Works management?

5. What electrical engineering subjects should be included? Principles of electrical engineering? Dynamo laboratory? Electrical measurements?

6. What civil engineering subjects besides hydraulics should be taken? Surveying? Mechanics of materials? Testing laboratory?

7. What in your opinion is the main cause of the failure of the present courses in chemical engineering to " produce men who are prepared in the best possible way for practical work in the manufacturing establishments of the United States"?

THE TRAINING OF CHEMICAL ENGINEERS

By M. C. WHITAKER

Read at the New York Meeting, Dec. 7, 1910.

MUCH attention is properly being centered upon the education of men in the scientific development and management of agricultural production, and the Government not only gives direct financial support to a large number of schools for such training, but also maintains a Department of Agriculture, the function of which is largely educational.

The annual production of the chemical industries is almost equal in value to the agricultural production of the country, and it is therefore proper to compare the facilities now being provided and the means now being adopted for the education of men to develop and manage the widely diversified units of chemical manufacture with the methods and facilities in other educational fields. Obviously the general educational and technical equipment of men to develop and direct processes or works depending upon the applications of chemistry, and usually involving a knowledge of power development and mechanical and electrical machinery is much greater than the technical equipment required for men in agricultural production. While agricultural education has grown and developed at a rate commensurate with the producing power of that industry, and has been fostered by private, State and Federal funds, education in the equally important and essential field of chemical manufacture has been, in some institutions, entirely ignored, in others only indifferently provided, and in no single case supported and equipped on a basis comparable with the wealth-producing power of the industry.

Efficient production and the economic management of our manufacturing plants are essential features to our commercial development, and it is in this field that the greatest results are to

be attained in the conservation of our natural resources. The accomplishment of these results obviously depends upon the application of scientific knowledge to the solution of all problems, both great and small, in the development, the direction and the management of our factories.

The chemical industries very properly look to the schools for men qualified to produce these results, to improve their production and manage their works. The best evidence that more and better trained men are needed in the chemical industries is the fact that this Institute of Chemical Engineers, composed of men of experience and men now engaged in the direction of great industries, meets twice a year and devotes a large portion of its time to the study of the problem of how to obtain trained men to assist them in the development and administration of their work.

Every employer of chemical talent knows that at best the young graduate is only a vague "prospect," and that much has been left undone in his training.

The problem of proper training and correct methods of teaching chemical engineering is one which must be carefully analyzed and studied from its very foundation, and is not one to be remedied by a few trivial changes in existing curricula—by dropping this and substituting that. The subject must be opened up and examined to its foundation and if it is found that the present structure is built on sand we should put some "concrete" under it.

Necessarily, the problem must be solved by the co-operation of the teachers with the employer of chemically trained men, and the writer, having served a term of practically ten years in each of the above fields, begs to submit a few observations and conclusions for the consideration of the Institute Committee on Chemical Engineering Education.

The chemical industries require for their development and management two classes of men of somewhat different training, natural qualifications and range of service.

First: Research chemists who are qualified naturally and by training to originate and to develop new fields. The training of the research man is more advanced, or supplements that of the chemical engineer, and the research results furnish the foundations for the industries which the chemical engineer organizes

and administers. In other words, the research chemist works in the new and undeveloped fields of chemical knowledge and produces results calculated to contribute new knowledge and new arts.

Second: The chemical engineer works in the organization, operation and management of existing or proposed processes with a view to building up a successful manufacturing industry. He uses his classified knowledge of chemistry and the allied engineering branches in developing, perfecting, organizing and administering a plant or a process for the production of a marketable and useful product at a profit to the investor.

Such a field as this requires a man of knowledge, originality and resourcefulness. His fundamental training in chemistry, physics, mathematics, etc., must be thorough and must be combined with a natural engineering inclination and an acquired knowledge of engineering methods and appliances. His originality and imaginative capacity seem to me to be essential, and the result of a combination of natural qualifications and training. Resourcefulness, however, comes as a result of experience in application and the ability to adapt a wide range of methods and practices to new conditions. A man with the natural qualifications, supplemented by the proper training, may become a successful chemical engineer.

The success of the research chemist is measured by his scientific achievements, whereas the success of the chemical engineer is measured by his commercial results. While their work bears a certain mutual and cyclic relation, it must be apparent that their natural and educational equipment may be entirely different.

The development of specialized training in certain selected lines of manufacture is not a proper function for an engineering school, but should be left to the trade school, or to the industries themselves. Specialized research, on the other hand, should be carefully eliminated from the regular engineering training and provided for in graduate courses.

For convenience in discussion, I have divided training subjects for the chemical engineer into three general classes: Fundamental, associated and supplementary. No attempt is made to discuss the details of the curriculum, the general purpose being to get broad subdivisions as a starting point. The question of arrangement of subjects into a curriculum and the proper

allotment of time for the course depends upon what is finally determined as proper training for the men under discussion:

Chemistry Physics Mathematics Allied subjects	Fundamental training.
Electrical Engineering Mechanical Engineering Civil Engineering General Engineering Business economics	Associated training.
Study of the *applications* of the fundamental and associated training in laboratories equipped with the "tools of the trade," and with working plants. Training, by "contact" and by "example," in a laboratory managed as an approved business, in the principles and practices of efficient organization and administration.	Supplementary training.

Fundamental Training: The training in the fundamental subjects need not be materially changed except perhaps more attention should be given to the laboratory facilities and to the selection of instructors for the fundamental work. Profound scholarship and a record for original research are too often made the sole determining factor in the selection of teachers for these subjects. Research qualifications are of secondary importance in the selection of men to give the fundamental training to our chemical engineers. Such teachers might better be chosen from men physically, temperamentally and educationally qualified to present their subjects clearly, logically and enthusiastically to the student, and to present them in such a way as to quicken and hold his interest. Too often our undergraduates become muddled, discouraged, and even give up a subject because of its dry, disconnected presentation or because the instructor "talks over their heads" or lacks the personality and the power to interest them. Research instructors are often permitted to

emphasize their "hobbies" or teach their special experiences without regard to the purpose of the course and its relation to the fundamental training. Our instructors should always be chosen to fit the course requirements and should not be permitted to divert the work into special fields not contemplated in the basic formulation.

The training in the fundamental branches should be more thorough and carefully proportioned than at present, keeping in mind that the chemical engineer's knowledge must be classified, complete, and accurate in the broad principles and not statistical, encyclopediac, or of the class of deep profundity required for research in new and original fields. The chemical engineer's knowledge is to be used as a basic "tool" of his trade, and may be given as such without detracting one iota from its value as mental training.

Associated Training: Associated training is for the purpose of placing in the hands of the chemical engineer a working knowledge of the other engineering branches, so that he may utilize them in the development and management of his particular problem. Courses designed primarily as foundational for future advanced study in the same field are not likely to be proper courses for this associated training. Our associated courses should be broad and general and need not carry the student beyond the foundational principles of the subjects with a working knowledge of the existing design, construction, materials, operation and use of engineering appliances.

The existing methods of teaching by lectures, demonstrations and laboratory work, combined with a liberal use of text and reference books is probably the most effective way of reaching the fundamental and the associated subjects.

Assuming that the student now has a thorough fundamental foundation in the basic principles of his profession and a working knowledge of the associated engineering branches, schools should be equipped for *directed* study of their *applications* to the problems of manufacture and production. This applied study is classed as "supplementary training."

In the education of teachers, in the education of doctors, in the study of agriculture and in the education of all other engineers except chemical engineers, training in the *application* of the respective fundamentals, under the direction and with the assist-

ance of experienced teachers, is considered essential. Medical schools without hospitals, teachers' colleges without practice schools, schools of agriculture without experimental farms, or engineering schools without laboratories and shops would hardly be dignified by classification as schools. Such institutions invariably invest large proportions of their resources in facilities for demonstrating the proper practical applications of the fundamental theories.

Is there any reason why chemical engineering should not and could not be taught by the tried methods of the normal schools, the medical schools, the agricultural schools and other engineering schools? Only with proper chemical engineering laboratories, equipped with real working models of standard appliances to illustrate the basic applications of the industries, and a proper curriculum arrangement to permit the student to study and use these appliances and the principles involved in their application will we be on a basis comparable with the methods and the facilities now existing in other educational fields.

But we can accomplish still more with proper laboratory facilities. We can so construct and administer these laboratories that the student will be surrounded by an "atmosphere" of manufacturing and business efficiency, where he will learn by *example*, by *daily contact*, by "*attrition*," the modern methods and practices of office and works management. Chemical engineers should have this knowledge. It is fundamental to the proper fulfillment of their job. Instances where failure has been converted into success and industries saved by a knowledge of proper administrative practices, and the application of business and works efficiency methods, are too numerous to mention. Refinements in chemical processes and ingenious mechanical devices are all ineffective and often useless if inefficient organization and management are permitted to absorb the earnings. Successful chemical manufacturing is based upon three general principles: First, chemical and physical facts; second, mechanical applications; third, organization and management.

The first principle is definite and basic and is, therefore, not capable of variation, but the second and third are variable and may be far from perfection. The greatest opportunity for increased profit therefore lies in the possibility of mechanical improvements and improvements in the efficiency of the organization. Instruction is provided in a greater or less degree in existing

schools in the two first principles mentioned, but the third equally important and fundamental principle is not even undertaken.

The " contact " system which I am urging for adoption as a method for teaching the principles and the applications of chemistry to manufacture, and for imparting a knowledge of the principles and practices of efficiency in organization, management and administration, are the same as the methods which have always obtained, by force of circumstances, in country schools where the small children in the A, B, C classes unconsciously absorb geography, history, arithmetic, etc., by hearing, seeing and being in the " atmosphere " of the more advanced work. This method can be adopted in the training of chemical engineers, and can be made infinitely more effective than in the country school.

The " contact " or " frictional " method would require a laboratory plant larger and more comprehensive than anything yet established and would have to be managed on somewhat different lines than those now obtaining in engineering schools.

If it is proposed to direct the student in the study of the *applications* of *fundamentals* of *factories*, *factory appliances*, *factory processes* and *manufacturing* business by the " frictional " method, the laboratory should be equipped, organized and administered as a live manufacturing proposition. There should be ground space enough to permit of the erection of one or more complete operating plants in addition to the general laboratories for the study of great applications such as distillation, evaporation, filtration, wet reactions, high-temperature oxidation, electrochemistry, etc.

The complete plants should be chosen from some of the important chemical processes of great common interest, which at the same time illustrate a wide diversity of chemical principles, appliances and products—for example, the manufacture of gas.

These plants should be designed and built from the foundation to the roof so that the structure itself, materials used, equipment, and arrangement would illustrate the best known practice and permit of the most ecomonical management and operation. Every structural detail should be provided with a view to *educating by example*. Office appliances, office systems and facilities should be provided and the equipment include books, trade journals, patent literature, samples, advertising matter, house organs,

etc., of the business. Conference facilities should be provided in each laboratory for lectures, discussions, demonstrations of the chemical, mechanical and business features of the process. All such work should be conducted in the special laboratories, and the student from the time he enters until he leaves should be made to "stumble over" the tools of his art and become "saturated" with the "atmosphere" of the business from the raw material to the market.

The classes should "go the rounds" of the laboratories in convenient-sized sections for conferences and for "manning" the work.

In connection with the chemical engineering laboratory there should be a "shop organization" consisting of competent mechanics, helpers, and laborers, necessary for the upkeep of the plant, and this organization should be so administered that our students would gain actual experience in dealing with workmen. Office experience, correspondence, dictation, filing and recording, fundamental costing, etc., may all become familiar knowledge to the student by having these facilities arranged for his use and by incorporating them in his daily "business."

Technical Advisers

These laboratories of engineering chemistry should be organized with a system of technical advisers to be selected from representative experts in each typical field of industrial chemistry. These advisers should be specially qualified experts or active works managers of live concerns. Their connection with the laboratory should not be merely nominal, but should carry with it a responsibility for the proper equipment of the special laboratory of the industry which they represent. They should also give some lectures upon their specialty, not altogether from the chemical standpoint, which presumably can be covered by the regular instructors, but from the business, organization, and relative industrial standpoint.

The personal contact and acquaintance between adviser and student is an obvious mutual benefit. The attitude of the leading industries toward such a chemical engineering school would become one of personal interest instead of one of criticism.

The technical advisory system, if properly initiated and admin-

istered, will insure modern equipment, methods, and instruction in chemical engineering and will give, through the lectures, first-hand and accurate general information on the scope and magnitude of the typical industries. Furthermore, it will definitely dispose of the frequent reference to obsolete and antiquated methods and equipment. By relying upon the judgment of these experts and managers of live and paying industries we would avoid the equally dangerous extreme of becoming loaded up with impractical, untried appliances and uncommercial processes.

Industrial Research

The largest industrial corporations, such as the General Electric Company, the United Gas Improvement Company, the National Electric Lamp Association, etc., have established and are maintaining research laboratories. These laboratories are directed in their chemical and physical research by able and high-priced men and are equipped and maintained at great expense.

Such laboratories are being established because there are no existing equipments, on a suitable scale, for solving the problems necessary for their industrial advancement. The corporations have not undertaken the burden and expense of academic research from choice, but from necessity. Our scientific institutions have utterly failed to provide the facilities for industrial research, and as a consequence are being " elbowed " aside from their natural position of technical and scientific leadership.

Under existing conditions the small manufacturer, who cannot afford to equip and maintain a research laboratory, has no prospect of solving his industrial problems. Unless the scientific institutions develop modern chemical engineering laboratories, equipped with the tools of the industries, and place their facilities within the range of the small manufacturers, industrial development will be limited to the few concerns whose means will permit the establishment and maintenance of .laboratories for private research.

On the other hand, with such laboratories as I have outlined, equipped with every facility for experimentation on a large scale, factory managers, technical laboratories and individuals could be interested in availing themselves of these facilities and in establishing industrial researches for solving industrial problems.

Frequent reference has been made to the cost of such a laboratory of engineering chemistry as has been outlined. We are dealing with a great industry and a great problem and we should therefore exercise our sense of proportion. It is estimated that the minimum *net profit* of chemical manufactures is $300,000,000 annually. It is also estimated that the combined investment in chemical engineering equipment in all of the educational institutions of the country is not over $30,000, or one-hundredth of one per cent of the net profit of the industry for one year. A $30,000-dollar investment or even one hundred times that is an absurdly small equipment to be devoted exclusively to instruction in the application of chemistry for such an enormous and profitable industry, not to mention the facilities for research development. If the plan outlined will produce men better qualified to enter this field of industry and men who can "deliver the goods," I have no fear that the question of cost will ever prove an obstacle to the development of such laboratories of chemical engineering.

QUESTIONS

First. Is the definition of a chemical engineer and the outline of his requirements substantially correct?

Second. Is the prevailing system of education adequate to produce the chemical and engineering talent needed in the industry?

Third. Does the present method of training chemical engineers produce men comparable in their respective qualifications with civil, mining and mechanical engineers?

Fourth. Do factory managers find our graduates qualified to assist in building up and developing the business or, are they simply "prospects" who must be "educated" at the expense, in time and money, of the industry employing them?

Fifth. Are men who receive their experience in the application of the fundamentals in the works where they are employed narrow in their perspective and limited in resourcefulness?

Sixth. Is there any reason why chemical engineering should not be taught by instruction in the applications of the fundamentals, in a similar manner to other educational systems?

Seventh. Are the subjects included under "supplementary

training " desirable or essential, and is the " frictional " method suggested a proper way to present them?

Eighth. Would a laboratory of engineering chemistry, equipped and managed as outlined, maintaining a rigid standard for entrance and for graduation, come nearer fulfilling the needs of men in the chemical industries?

Ninth. Would manufacturers avail themselves of the facilities of such a laboratory for industrial research?

Tenth. Should such a laboratory be organized and administered both in its relations to the students and to its work, as a live, up-to-date business?

TEACHING INDUSTRIAL CHEMISTRY

By A. H. SABIN, of the National Lead Co.

Read at the New York Meeting, Dec, 7, 1910.

THE most prominent fact about instruction in industrial chemistry appears to be that we have in this country at least a dozen schools where good instruction may be had in every other sort of engineering to one where serious attempt is made to teach technical chemistry. Where these attempts are most successful they are narrow in scope, as in the Textile School in Philadelphia and the like, where practically a single line is taken. The need of good schools in this subject is to-day more urgent than any other one thing in the educational line. Even agriculture, the teaching of which lagged behind almost everything else (although the most important thing in the world), is well taught, in comparison. This is a matter in which there is agreement among the technical and manufacturing chemists of the whole country; at every general chemical meeting it is their universal cry. The whole progress of manufacturing is being held up by this. Plenty of men may be had who possess executive ability, and knowledge of economic conditions has received great attention for some years; electrical and mechanical engineers abound; analytical chemists are not at all uncommon; but men with any considerable knowledge of industrial chemical methods are not provided by the schools.

The center of gravity of our manufactures will not always remain on the Atlantic slope. There are more chemists between the Missouri River and eastern Ohio, north of Kentucky and Missouri, than in New England, and it is time that our Eastern universities did something for those industries which support them. It is no longer enough to train men for a scholarly life. I would be the last to depreciate culture, but it is possible to have

a cultural or disciplinary treatment of the most practical matters; thus we have truly self-educated men, like Brashear. Culture is a good thing, and to be desired; at the worst, as a consolation for failure, its price is above rubies. Abstract science is necessary; it is fundamental; but it is only the crude raw material which becomes the finished product when it has passed through the hands of the industrial chemist and the engineer. In pure science a fact is viewed as an instance of a law; but in technology the fact has some interest and value in itself. Good practice, no doubt, is founded on good theory; but good theories have almost always been preceded by bad ones, and in most cases the practice was discovered first. Research does not mean abstract science; research is essentially an attitude of mind; it is just as desirable and attainable in utilitarian problems as in abstract ones. The spirit of research is evoked by situations which are real, pressing and urgent in their needs. To get the best results as intellectual discipline, a subject must be so taught as to get hard work out of the student and at the same time keep his interest, and the training of investigators in technical work cannot be done in a laboratory of pure science, but must be carried on where the conditions and appliances of such work are known. Only those trained in established methods are likely to show great originality; and the teacher in such a school should be a good investigator, but not every able investigator may be intrusted with instruction. Teachers must make scholars of others, and a man may be a good teacher and an investigator of technical problems who has not added anything to our knowledge of abstract science. All live men are not necessarily laboratory investigators. While specialists are often useful and successful men, they are no different from other men in having or lacking ability to teach, which is largely dependent on intellectual altruism; not only the ability, but the desire to enter into the student's view, and by comprehending this to lead him to correct knowledge and practical attainment.

As to what a school of industrial chemistry should be, it will be difficult to make people agree. It seems to me that it should start out by teaching how to conduct standard operations, e.g., in filtering, how to use the different kinds of filter-presses, and just what they will and will not do; bag-filtering, various types of straining and percolating; screw-press filters, sand-filters, and the use of filter-mass. In the same way teach evaporation, as

in open pans, single- and multiple-effect vacuum pans, mechanical dryers, air-blowing, spheroidal-state evaporations (many foods are now made in that way), and other commercial methods. The student should learn of fuel, fuel values, furnace construction and operation; construction and use, testing and economics of power plants, both steam and gas; same of electric motors and dynamos. Some knowledge should be taught of metallurgy, enough to have some idea of metals as materials of construction at all events. That is, teach standard operations and subjects of universal use, first; then specialize as much as seems desirable. As it is, not one student in twenty goes out of a laboratory knowing how to dump a carboy of acid, or open a drum of soda; there should be a stop put to that state of things.

Most of these things may be taught in such a way as to show their relations to the laws of chemistry, especially physical chemistry, and everything should be done not merely carefully, but accurately. There is no reason why the necessary preliminary and some of the concurrent instruction in general and analytical chemistry and physics, and engineering, may not be taught in the schools especially devoted to these subjects, supplemented by special work on the more purely industrial lines. There is no conflict between theory and practice, and all the schools of a university should work together for the common good.

COMMERCIAL MANIPULATION OF REFRACTORY ELEMENTS FOR INCANDESCENT LAMP PURPOSES

By RALPH E. MYERS

Read at the Niagara Falls Meeting, June 24, 1910.

THE modern incandescent lamp makes demands on the refractory elements for two purposes, which, upon final analysis, we find quite similar: first for the filament, the conducting body, which in the incandescent state partially transforms the electrical energy into light; second, for the supports which "anchor" or hold the hot semi-plastic filament in the proper position while burning. The ideal element for the filament will have a very high melting point, low vapor tension under working conditions, and a highly selective radiation.

The high melting point will permit of a high operating temperature. Since Waidner and Burgess* have shown that at the operating temperatures of our metallic filament lamps the intensity of light emitted varies as the twelfth power of the temperature while the energy supplied varies only as the fifth power of the temperature, it is evident that much better efficiency can be obtained by the use of a filamentary substance which can be burned at even slightly higher temperatures.

The practically infusible element carbon would seem to be ideal for filament purposes. However, the vapor tension resulting at high temperatures is such that the operating temperature of even the most improved type must be reduced to such a point that the efficiency is less than half that of the best metallic filament. The element molybdenum should give a fairly efficient lamp, but its high vapor tension under working conditions makes necessary such a reduction in the temperature of burning (to obtain a sat-

* Waidner and Burgess, Bulletin of Bureau of Standards, Vol. 2, No. 3, page 319, 1907.

isfactory life), that it is less efficient than the ordinary carbon lamp.

In defining selective radiation it is convenient to refer to "black body" radiation. A body which follows the Stefan-Boltzmann law is called a black body. The law states that the total radiant energy is proportional to the fourth power of the absolute temperature. At a given temperature not only is the total radiation from such a body, but also the radiation for each wave length is greater than that from any other known source. All metallic filaments show selective radiation to some extent. They may give out less total radiation than a black body at the same temperature, due perhaps to the condition of the surface, or they may give relatively more radiation of the shorter wave length (light) and less of the longer wave length (heat) than a black body at the same temperature. According to Waidner and Burgess * the radiation from a carbon filament most closely approximates a black body radiation throughout the visible spectrum, yet is much less in its total radiation. Platinum departs most widely from black body radiation; that is, it is the most efficient metal at the temperature at which it can be used. Tantalum is more selective in its radiation than tungsten, hence it would be a more efficient filament if it could be operated at as high a temperature.

In addition to the points just mentioned, an element to be useful for lamp purposes must fulfil certain practical requirements, such as low cost and general workability.

As the efficiency and burning temperature of the filament increase, more attention will be given to the composition of the support. It is true that metals of low melting point can be used as filament supports by using wire of sufficiently large diameter. But such a practice would certainly be bad lamp design, from both the mechanical and electrical standpoint.

The ideal lamp will have a minimum number of filament supports and these will be of the smallest dameter consistent with practicability. This will make necessary an element of high melting point and low volatility. Since the glass stem is a relatively poor heat conductor, most of the energy consumed in the burning lamp is radiated from the filament and its supports. Therefore,

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* Waidner and Burgess, loc. cit.

an anchor with a polished surface will be of value since it will radiate a minimum amount of heat and consequently produce a minimum local cooling. The demands made upon the support, although of the same nature as those made upon the filament, are not nearly so exacting. Nevertheless there are very few metals which approach the ideal.

Development of High Efficiency Lamp. Since the advent of the incandescent lamps some thirty years ago there has been such an increase in the demand that to-day the various factories in the United States alone are called upon to produce hundreds of thousands daily. During this time the earlier types have been greatly improved and entirely new ones developed. The carbon filament lamp is still with us, but in an improved form. The osmium lamp has come and gone: practically driven out of the market by the tantalum lamp, which can be produced more cheaply. The most recent development, the tungsten lamp, is gradually displacing all other types, owing to its high operating efficiency.

You see before you examples of four kinds of lamps which are now offered to the purchasing public. The regular carbon lamps burn at 3.1 watts per candle, the metallized carbon lamp burning at 2.5 watts per candle, the tantalum lamp burning at 2.0 watts per candle, and the tungsten lamp burning at 1.25 watts per candle. The carbon and the metallized carbon lamps are 50-watt lamps, and the tantalum and tungsten lamps are 40-watt lamps, so that the individual lamps do not illustrate the relative candle power obtainable from a fixed amount of electrical energy. With our present knowledge of the elements, tungsten, with an operating efficiency of 1.25 watts per candle will probably remain the element par excellence for filament purposes for some time to come.

Characteristics of the Tungsten Filament. You have before you (Fig. 1, page 173) four tungsten characteristic curves showing the approximate variation in voltage, current candle power and life (expressed in per cent) with the variations in efficiency. At the extreme left you will note that as the efficiency improves (denoted by numerical decrease in the watts per candle) the current increases slowly, the voltage more rapidly and the candle power very rapidly while the life decreases very rapidly. At the extreme right you will also note that as the efficiency becomes

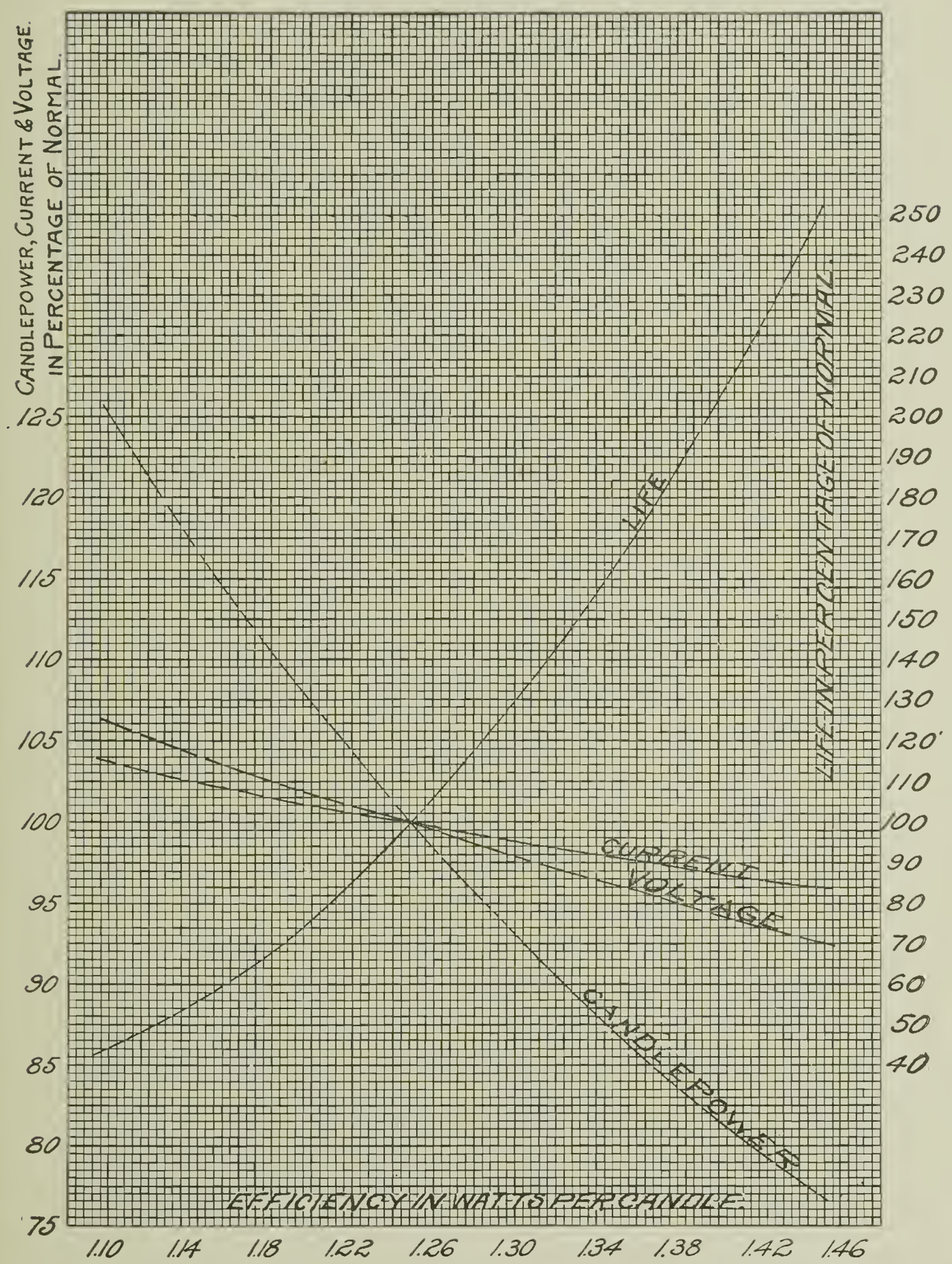

FIG. 1.—Approximate Characteristic Curves of Tungsten Lamps.

poorer the current drops off gradually, the voltage more rapidly and the current very rapidly. On the other hand the life curve shows a rapid rise as the efficiency drops off (numerical increase in watts per candle).

The efficiency can be varied in both directions beyond the limits of the present curves, illustrating the point that a tungsten filament can be burned at almost any efficiency. Of course, for commercial purposes there is a certain economic efficiency which depends upon the wattage of the lamp, the cost of lamp renewals and the cost of electrical energy. The wattage of the lamp becomes an element through the fact that the lamps which are high in total watts can be burned at better efficiencies than the smaller lamps, without giving a short life. In other words, under certain conditions it is cheaper to use up more lamps by burning them at better efficiencies than to obtain long life at the lower efficiencies. For this reason lamps are put on the market with efficiencies varying from 1.33 watts per candle for 25-watt lamp to 1.15 watts per candle for the 250-watt lamp.

Tungsten Filament Manufacture. Tungsten filament manufacture as it has been practiced may be conveniently divided into the following five topics for the purpose of description: purification of raw material, preparation of plastic mass, filament making, preliminary heating and final heating. These topics will be taken up in the order mentioned.

Purification of the Raw Material. The American market for crude tungstic acid is supplied chiefly by Wolframite from Colorado and Scheelite from California, although some ore, principally Wolframite, is imported. The finely divided Wolframite is commonly fused with sodium carbonate. After filter-pressing off the oxides, etc., insoluble in water, the solution is treated with hydrochloric acid to acid reaction. The rather insoluble sodium paratungstate crystalizes out when the solution cools. Sodium molybdate, silico- and phospho-tungstates remain in the mother liquor. Commercial tungstic acid is obtained from the paratungstate by an acid treatment.

Whatever method of filament manufacture is used, high purity of material is necessary. The purification process described by Smith and Exner * has given perhaps the purest tungstic acid

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* Proc. Amer. Phil. Soc. 43, 123.

ever produced. By their method, ammonium paratungstate crystals are added to a boiling mixture consisting of nitric acid diluted with an equal volume of water. Portions of hydrochloric acid are added from time to time and the heating is continued until only traces of chlorine remain. After washing, the purified oxide is reconverted into paratungstate. This method of procedure is repeated until the resulting oxide will dissolve without residue when digested with dilute sodium carbonate solution.

Of all the impurities which may be present in the purified ammonium paratungstate, or the tungstic acid obtained therefrom, molybdenum, arsenic and phosphorus are perhaps the most objectionable from the standpoint of the life of the lamp. Since nothing more than a trace of these elements is permissible, every precaution must be taken in the way of factory control to check the various operations of the purification process.

Preparation of the Plastic Mass. In cases where filaments are made from a paste, at least three distinct methods may be used in the preparation of the plastic mass which yields a thread-like structure called a filament when forced through a diamond die.

First Method. Oxides or other similar compounds of tungsten may be worked up with an organic binding agent to produce a workable mass. The brown WO_2, or the violet W_2O_5, owing to their conductivity, are preferable to the trioxide. Nitrocellulose dissolved in amyl acetate, gelatin, starch, tragacanth, etc., may be used to bind the mass together.

Second Method. Tungstic acid may be reduced by hydrogen or other reducing agent to produce a finely divided black or gray tungsten metal. The latter may be used with an organic binder, such as mentioned above, or dissolved in an amalgam of cadmium and bismuth which is forced through a die when hot to give a thread-like mass.

Third Method. Ammonium tungstate or tungstic acid under certain conditions may be worked up into a pasty mass, which, without the addition of any binding agent, will flow under pressure.

Filament Making. Continuing the description of the processes mentioned in the foregoing, the plastic mass obtained by any of the above-mentioned methods is placed in a container having a diamond die at the bottom and subjected to pressures varying from about three to six tons per square inch. The plastic mass leaves the die in a continuous thread of uniform diameter. This is

usually caught on a card which is moved back and forth to give double loops. These are cut at the middle of the card so as to give the hairpin shape which is retained in the finished lamp. In most cases the filament at this stage is practically a non-conductor.

The dies used in this process are made from diamonds and their apertures range in diameter from about .001 inch to .015 inch. As the diameter decreases the difficulties increase to such an extent that the filament making operation becomes almost an impossibility without painstaking scientific supervision of each step in the manufacture.

Provided that a uniform shrinkage and a smooth surface can be obtained, that plastic mass is to be favored which will give the greatest shrinkage from the die diameter down to the finished diameter of the filament. Under practical working conditions it makes considerable difference whether an .0012 inch or .0020 inch die must be used to obtain .001 inch filament.

Preliminary Heating. The hairpin shaped filaments obtained as just mentioned are given a prelminary heat treatment with the object of lowering the resistance. This is usually necessary to get the filament in suitable shape for its final heating, which is always under current. This heat treatment, of course, varies with the composition of the plastic mass used. Filaments consisting of oxides or other similar compounds of tungsten with organic binders are heated either to 400° or to 1200° C. in hydrogen. At the lower temperature residual carbon from the binding agent together with the rather poorly conducting oxides gives the desired conductivity. At 1200° C. both the carbon from the binder and the oxygen from the oxide are driven off and the metallic particles are sufficiently sintered together to conduct.

If the filament contains tungsten metal and an organic binder a temperature of some 600° C. is used in a non-oxidizing atmosphere produced by the decomposition of the binding agent. As above, the residual carbon lowers the resistance of the mass. Filaments consisting of metal and an amyl acetate solution of nitrocellulose are heated slowly in a vacuum up to 1200° C. The result is a partially sintered mass nearly free from carbon and of good conductivity.

The filament produced by the "amalgam" process, although of fair conductivity, requires special heat treatment, since about

seventy per cent of its weight consists of mercury, cadmium and bismuth, which have to be removed. The filament must be carefully heated, preferably in a vacuum. The greater part of the alloying metals leave at comparatively low temperatures, the final traces being removed in the final heating.

Final Heating. After the preliminary heating by one of the methods just described, every tungsten filament, regardless of the plastic mass from which it is obtained, must be put under current to remove the last traces of the binding agent and to thoroughly sinter the particles of metal together. This sintering must be so performed that the resistance of the filament will not change appreciably during prolonged burning.

Since tungsten is easily oxidized when heated in the air the final heating must be performed in a reducing or at least a non-oxidizing gas.

The voltage-current curve as given in Fig. 2 shows the changes which take place during the final heat treatment in a rather high resistance filament which has been prepared by the second method. At " A " you see a gradual decrease in the voltage increment necessary to produce a given increase in current up to the peak of the curve. From the peak down the leg of the curve marked " B " the voltage decreases as the current increases. In that portion of the curve marked " C " there is an increase in voltage required to produce an increase in current.

In the portion of the curve marked " C " we have the characteristic of a metallic conductor. This means that the chemical changes and the sintering have taken place in the portions " A " and " B." It is difficult to prove without extensive analytical work just where the chemical action takes place, but it is probably at the peak of the curve. The necessary heat to start the reaction is produced in the leg " A " and the removal of the last traces of carbon and final sintering take place at " B." A filament made up by the first method shows a much broader peak, indicating more extensive chemical action.

The increase in current with the decrease in voltage in the portion of the curve marked " B " makes necessary the use of a ballast resistance. As the resistance of the filament decreases the ballast consumes more and more of the voltage drop. It is evident that the steady application of the voltage used at the peak would produce a melting off of the filament in a very short

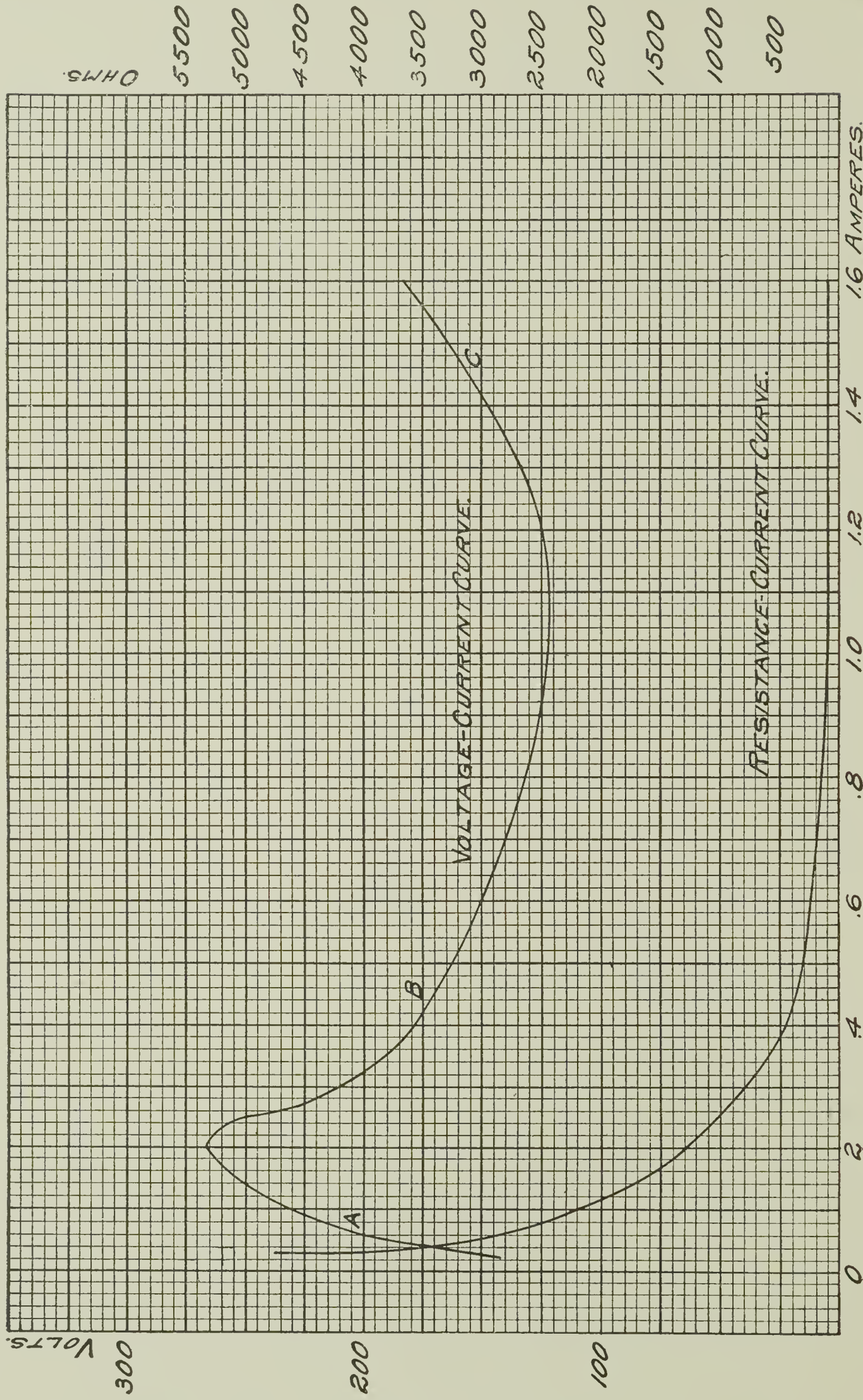

FIG. 2.—Final Heating Under Current.

time. By using a high ballast resistance and a high voltage, the final heating can be performed without injury to the filament. The ballast resistance and the voltage required to carry the filament over the peak are variables which must be adjusted for the various sizes of filaments.

The resistance-current curve in Fig. 2 shows the progressive changes in resistance during the heat treatment. You will note that the resistance is practically constant at the end of the operation.

New Method of Manipulation of Refractory Elements. During the past eighteen months the engineering department of the interests with which I am connected has done some very important work in the development of the manipulation of refactory elements, which has resulted in the perfection of a complete process along novel lines. It must be obvious to you that, owing to commercial phases of such a process, I am unable to give complete details.

Several important patent applications, however, have been filed, and as soon as the cases are issued from the Patent Office, I will probably be able to give some very interesting facts regarding same.

This new method of manufacture has made possible a new type of lamp known commercially as the tungsten "wire type" lamp, and has been instrumental in making possible the manipulation of several other refractory elements, one of the most important of which is molybdenum.

A filamentary structure of molybdenum has been obtained without difficulty, and for the purpose of giving an idea of the practical working out of this process, I have with me several samples of molybdenum wire for examination.

Properties of Molybdenum. The molybdenum metal which is seen in the coils has considerable flexibility. It can be wound around the fingers, and in most instances it can be drawn down into quite a small knot before it breaks. After drawing, it develops quite an elasticity, which seems to increase as the reduction progresses. The undrawn molybdenum is rather soft, in fact, it can be easily polished by rubbing with the blade of a knife. Hence, it is not at all surprising that it can be drawn cold. After drawing, it develops a smooth surface which is quite noticeable in the specimens wound on the spools.

Since the filamentary structure can be produced in practically any diameter, the drawing of the material has not been given much attention. However, reductions have been made in the cold to fifty per cent of the original cross-section. The tensile strength after such a reduction increases from about 80,000 lbs. per square inch to 130,000 lbs. per square inch, and it would probably go higher with further drawing.

The malleability of the element is nicely shown by the sample of ribbon which has been rolled in the cold from .006 inch down to .001 inch. The thinnest ribbon which has been produced measured .0005 inch in diameter. The metallic luster and color of the element appear to advantage in the sample of the ribbon.

The density of the unworked metal is about 9.65. This increased on drawing and reaches a maximum of 10.24 in the rolled material.

The metal in the filamentary form has a specific resistance of 7.03 microhms per centimeter cube. This value decreases to 6.23 microhms after a 40 per cent reduction in the cross-sectional area of the wire.

To illustrate the differences which exist between the elements tungsten and molybdenum, fused type lamps of equal resistance were made from the two elements and then readings of current and candle power were obtained for gradually increasing voltages.

Curve " A," Fig. 3, is the ampere-volt characteristic for the tungsten filament, and curve " B " is the ampere-volt characteristic for the molybdenum filament. By comparison with the curve " C," which is the theoretical ampere-volt characteristic of a substance with a zero temperature coefficient, we see that the positive temperature coefficient of these metals causes their curves to rise quite rapidly. The upper portion of the curve " B " follows the tungsten curve quite closely until 130 volts is reached. Further increase in voltage produces a rapid volatilization of the metal which causes a sudden drop in the candle power and a sudden increase in the resistance which so decreases the current that the curve takes the peculiar form shown.

Curve " D " is the candle power-volt characteristic for tungsten and " E " the corresponding curve for molybdenum. Please note

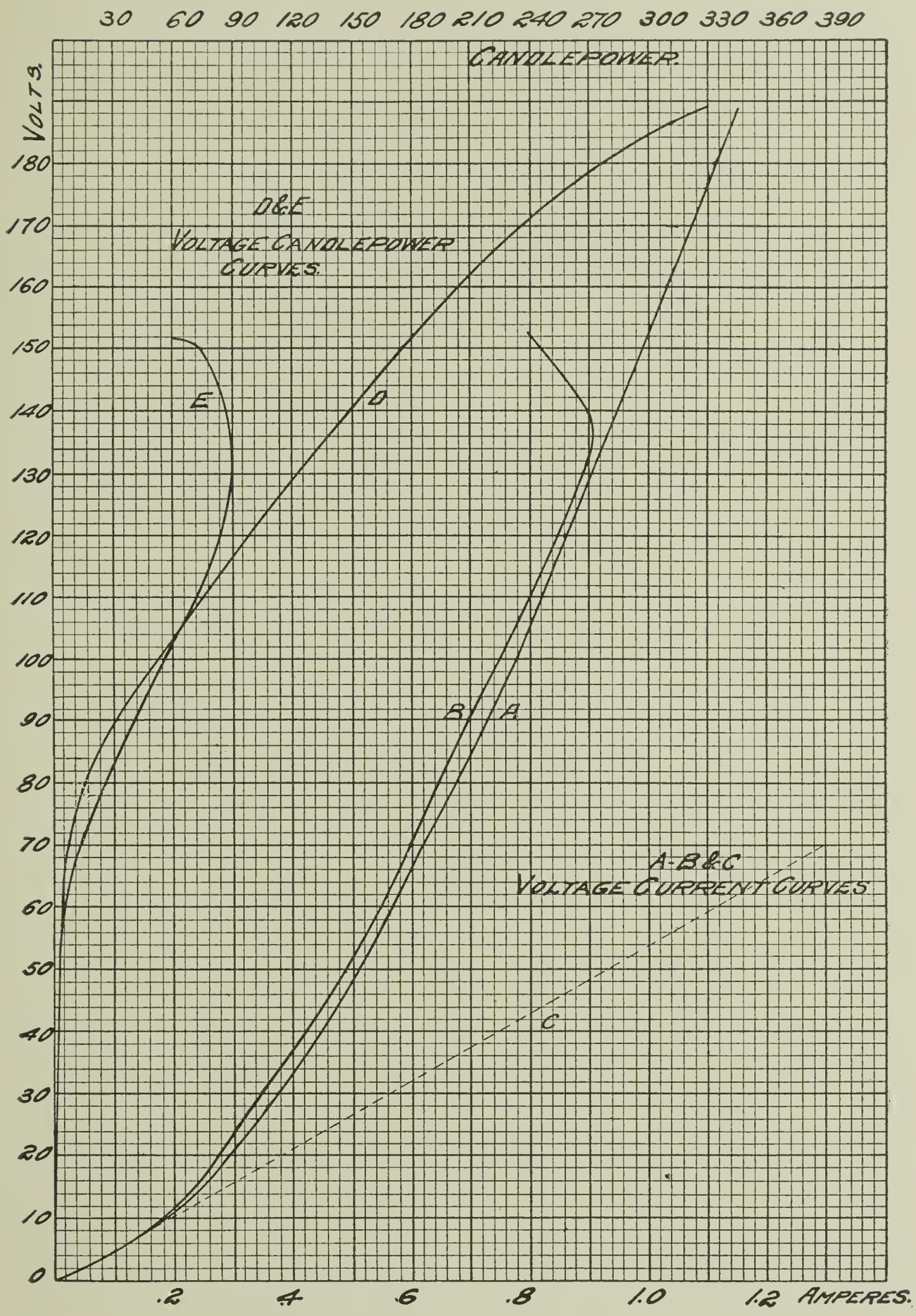

FIG. 3.—Voltage-candle Power and Voltage-current Curves.

that the candle power, curve " D," rises rapidly at the higher temperatures for slight increases in voltage. The hook on the end of the curve " B " shows the sudden decrease in candle power due to the volatilization of the metal.

Curve " A," Fig. 4, shows for tungsten the variation in candle power with the variation in the watts per candle. Curve " B " is the corresponding curve for molybdenum. That portion of the curve " A " between 60 and 110 candle power is a duplication of the same characteristic given in Fig. 1. Curve " A," Fig. 4, therefore covers a much larger field.

It is evident from a consideration of Fig. 4, that molybdenum is a very inferior substance for filament purposes, practically worthless. The volatilization at 80 candle power (1.4 w.p.c.) causes almost instantaneous blackening, while tungsten shows no indication of this volatilization at 360 candle power (.6 w.p.c.). The lamp would have a life of about 25 hours at this high efficiency. Molybdenum, however, is suitable as a material for filament supports, and it will doubtless be used quite extensively for this purpose.

The foregoing work on molybdenum has been done quite recently and the results which have been given are not necessarily the best that can be obtained since the metal here shown is not especially pure. It contains .004 per cent of arsenic, .028 per cent of iron, .029 per cent silica and .047 per cent of lime, etc., while it is nearly free from carbon. Of course, such impurities can very materially modify the properties of the metal.

The New Wire Type Lamp. As before stated the new process has made possible a series of new lamps, which you now see burning before you. These lamps range from twelve candle power to 500 candle power, all of the 110-volt grade.

You will note that the hairpin filament, common to the old method of manufacture of tungsten lamp, is absent, and in its place we have the new wire type construction made in accordance with the new process. The wire type is very much superior to the fused type from both the electrical and mechanical standpoints. The structural advantages of this new lamp were well brought out in a paper presented by Mr. C. F. Scott, Consulting Engineer of the Westinghouse Electric and Manufacturing Company before the National Electric Light Association at their recent convention

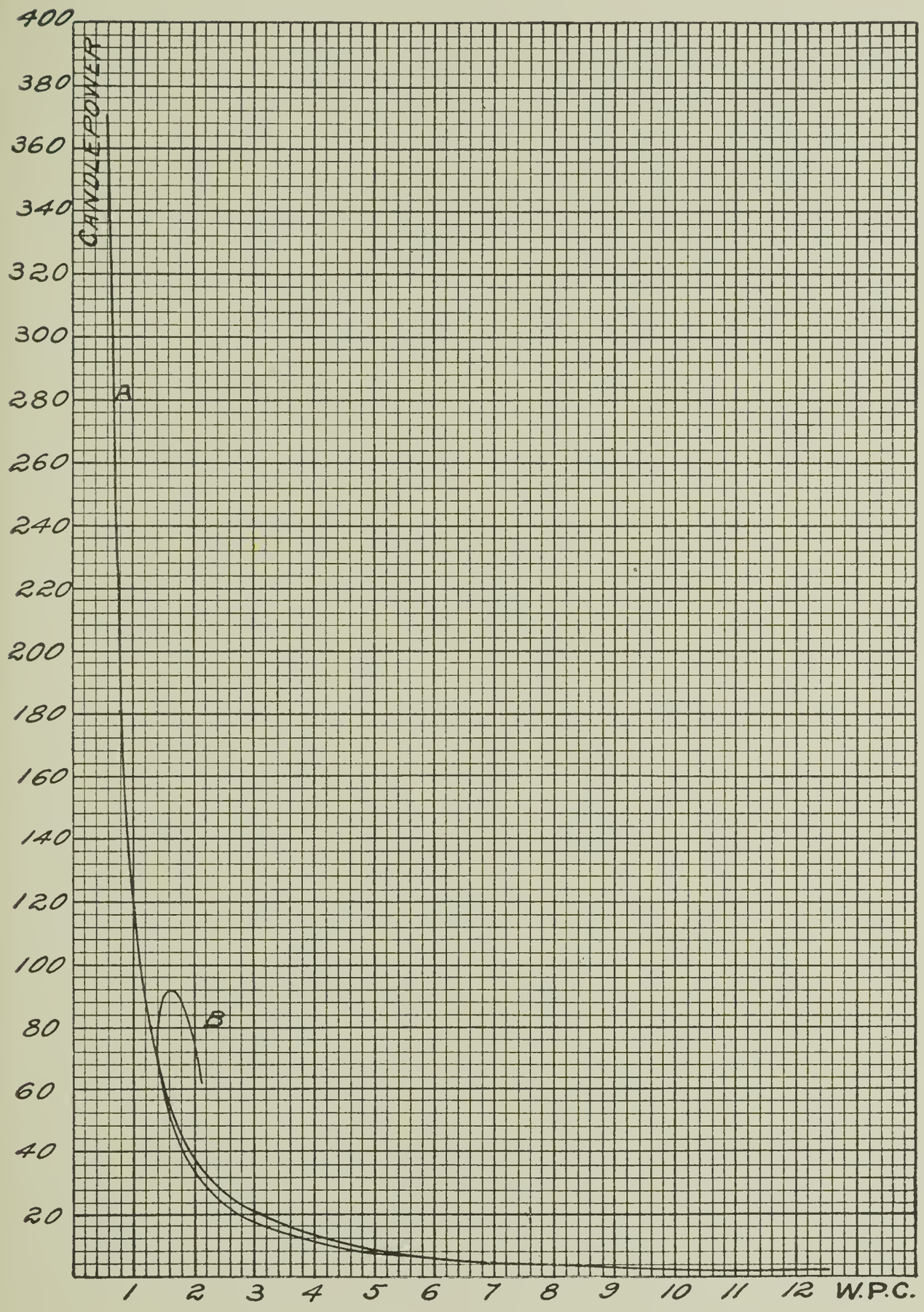

FIG. 4.—Candlepower-watts Per Candle Curves.

in St. Louis, from which I quote the following table, illustrating the shock-resisting ability of the new types;

Lamps Vertically Pendant.	60 Watts.		40 Watts.		25 Watts.	
	Wire. Inches.	Fused. Inches.	Wire. Inches.	Fused. Inches.	Wire. Inches.	Fused. Inches.
Five weakest....	33.6	3.6	32	6	14.8	2.0
Five strongest...	40.0	14.0	40	12.4	17.6	5.6
Average.....	36.8	8.8	36	9.2	16.2	3.8
Ratio	4.21	1.0	3.9	1.0	4.3	1.0
Horizontal.						
Five Lamps.....	.....	.....	40	6.4	36.8	6.4
Ratio	.....	.....	6.2	1.0	5.7	1.0

In making these comparative tests the lamps were screwed into sockets mounted on a board in such a way that part of the lamps hung in the ordinary pendant position, while others were in a horizontal position. The sockets were so arranged that four lamps could be tested simultaneously, two of each type. An iron weight sliding on a vertical rod was allowed to drop on to the board, from varying heights, until the lamps were fractured. The heights in inches necessary to break the various lamps are given in the table. The results show that the 60-watt, 40-watt, and 25-watt wire type lamps, when in the vertical position, can withstand the dropping of the weight from about four times the height that is fatal to the fused type. The ratio increased to six to one when the lamps are placed in a horizontal position.

The great gain in mechanical strength of the wire type is due chiefly to the absence of rigidity. The filament hangs rather loosely in its supports, permitting more or less movement. The wrapped and fused terminals give at once good electrical contact and a certain resiliency which is entirely lacking in the fused type lamp.

From the electrical standpoint it is important that the four or five hairpin filaments which go to make up a lamp are of the same cross-section and the same specific resistance. The failure to obtain this condition may have serious effect on the life of the lamp, as will be shown. You see before you a lamp which has been made up to illustrate the point in question. In this lamp the filaments have been mixed purposely. The filament which is burning more brightly than the others has a smaller diameter

by about .00004 inch. In such a case the bright filament can scarcely have less than a three per cent over current. Referring back to the tungsten characteristic curves, Fig. 1, you will note that a current three per cent over the normal current will shorten the life to fifty per cent of its normal value. So the bright filament will burn out at about half the normal life of the other four filaments.

Of course, the above is an exaggerated case; such a lamp would be discarded in the factory inspection. The usual sorting of filaments by a cold resistance measurement is fairly satisfactory and does not give lamps in which this defect is visible to the eye. Nevertheless, among a number of dies of supposedly the same diameter, their diameters differ even when supposedly the same, and even a particular die will give filaments of slightly different diameter at different periods, and with the many variables before and after filament making, it is hardly reasonable to suppose that fused type lamps can be made without possessing the above defect to some degree.

In the wire-type construction it is obvious that conditions are most favorable for the avoidance of such a defect, for with filamentary structure in one piece, manufacturing difficulties both accidental and those inherent in the old processes practically disappear.

The wire-type lamps are also made in the 220-volt and low-volt grades. The latter are particularly designed to meet the requirements of car lighting, which is a very severe service. That the lamps are eminently suited to this purpose has been shown in the comparative mechanical tests.

The twelve candle power lamp was made only to show the possibilities in the direction of low candle power. Its manufacture is not contemplated since its general introduction would place too great a handicap on the central stations of the country. The 400- and 500-candle power lamps are designed to compete with the arc lamps. Since the 400-candle power lamp gives more light than the ordinary enclosed arc lamp and operates at a slightly better efficiency, the prospects look bright in this direction.

RESEARCH LABORATORIES OF THE WESTINGHOUSE LAMP CO.
BLOOMFIELD, N. J.

THE MANUFACTURE AND INDUSTRIAL APPLICATIONS OF OZONE

By OSCAR LINDER

Read at Niagara Falls Meeting, June 24, 1910

Introduction

Since its discovery in 1840 by Schoenbein, ozone has been a fascinating subject for investigation to many chemists and physicists. The vast commercial possibilities of ozone have been conceived by many scientists, and it is interesting to note the prophecy of Berthelot that ozone has an immense future and will ultimately work a veritable revolution in the chemical industry. The scientific literature and the records of the Patent Office will bear proof of the attention which has been paid to this remarkable gas by scientists throughout the world. There have been more than one hundred patents issued by the United States Patent Office on methods and apparatus for producing ozone, and the number of foreign patents is legion. It is true that most of them are based on the original method of producing ozone by subjecting air or oxygen to electrical stresses, and most of the claims are but special arrangements and combinations embodying this fundamental principle, or means for producing the electrical stress. However, there are some notable exceptions, such as, for example, methods of producing ozone by means of heat or ultra violet rays, although the efficiency of these processes at the present time is too low to enable them to compete successfully with the electrical method.

Properties and Occurrence

All chemists and most laymen know that ozone is a gas with the composition O_3, and that it is an allotropic modification of oxygen formed from the latter by an endothermic reaction. According to Berthelot, 29,600 calories are required to form 1 gram-molecule

of ozone from oxygen. Expressed in a popular way, ozone may be called oxygen in a highly energized form. As a gas, it occurs or can be produced only in greatly diluted form, but it can be condensed to a deep blue liquid of a specific gravity of 1.46, which boils at −106° C. according to some and at −125° C. according to other investigators. It is very unstable in either form and, upon standing, decomposes slowly if greatly diluted and may do so explosively if in liquid form. This decomposition takes place faster the higher the temperature, and at a temperature above 270° C. ozone cannot exist. Its density as a gas is 1.66, air being 1.

Ozone has a characteristic odor which is perceptible even when in extreme dilutions with air. So delicate is our sense of smell to this gas that it is possible to detect the presence of one part of ozone in about ten million parts of air, which would correspond to a concentration of 1/100,000 of one per cent. It is the most powerful oxidizing agent known and will attack, even when greatly diluted, all oxidizable and especially organic matter. It is, therefore, a valuable oxidizing agent, not only because of the ease of its application as a gas, but also because no other elements are introduced into the reaction but oxygen.

Ozone occurs in nature in the atmosphere and is supposed to be formed in small quantities through electric conditions of the atmosphere, and by the action of the ultra-violet rays of the sun upon the atmospheric air. This latter method of formation explains why it is more abundant in the higher regions where the ultra-violet rays are largely absorbed by the atmosphere. The quantity of ozone which is present in the atmosphere is largely a matter of conjecture. It has been given as from .1 to 12 parts in 1,000,000 parts by volume of air, but most likely it is present, even where most abundant, in quantities of not more than 1 in 1,000,000. We are not going much wrong if we assume it to be about .1 part in 1,000,000 parts air (1/100,000 of one per cent, or a little less than 1 mgr. per cubic meter of air). The very fact that even in smaller concentrations than this its presence can be detected distinctly by our sense of smell, while its detection by chemical means is, at best, uncertain, may be taken as an indication of its importance to our daily life.

Manufacture

Ozone can be made in a number of different ways, but the only method of commercial importance at the present time, is its formation through electric stresses. I might mention that a process of great interest and of commercial possibilities is the formation of ozone through the action of ultra-violet rays upon air, these rays being produced by means of a mercury vapor lamp enclosed in a quartz tube. Another method of scientific interest is the production of ozone by means of heat in which Nernst and Clement obtained fair yields (as much as $3\frac{1}{2}$ grams of ozone per kilo watt hour) by leading oxygen over incandescent bodies and cooling it immediately by liquid air. F. Fischer obtained equally good results by blowing air at a velocity of 50 meters per second through a slit 1 mm. wide over a Nernst burner, and then cooling it in a glass tube surrounded by water. However, at the present time these methods are too inefficient for commercial purposes.

The apparatus designed by Berthelot, a sketch of which is given in Fig. 1, is the prototype of most ozonizers which are on the market at the present time. Occasionally parallel plates are used in place of concentric tubes, but in general there is very little difference between the different designs and makes except as to construction. There may be either one or two layers of a dielectric material, which is usually glass free from lead, or mica separating two metal electrodes. The latter are used mostly in the form of aluminum or tin foil pasted to the dielectric or sometimes solid metal or metal brushes, which may or may not touch the dielectric. The thickness of the dielectric layer is usually in the neighborhood of $3/32''$, and that of the air space about $1/8''$, but these dimensions depend, of course, largely on the character of the electric energy. When the metal electrodes are connected to the opposite terminals of an alternating current of suitable frequency and voltage, a so-called cold or silent discharge, free from sparks, takes place through the glass and is visible by a faint violet glow distributed evenly through the air space between the electrodes. The air or oxygen to be ozonized is passed through this glow and is thereby ozonized. It is not definitely known whether it is the stresses themselves which cause the ozonization of the air or whether it is due to the ultra-violet rays which are generated in the air gap, but the latter theory seems more probable at the present time.

It should be mentioned here that the use of oxygen instead of air, while giving considerably higher yields and concentrations, has been generally abandoned on account of the costliness of the oxygen. A step-up transformer of high ratio and comparatively low current capacity, constructed on the principle of a potential

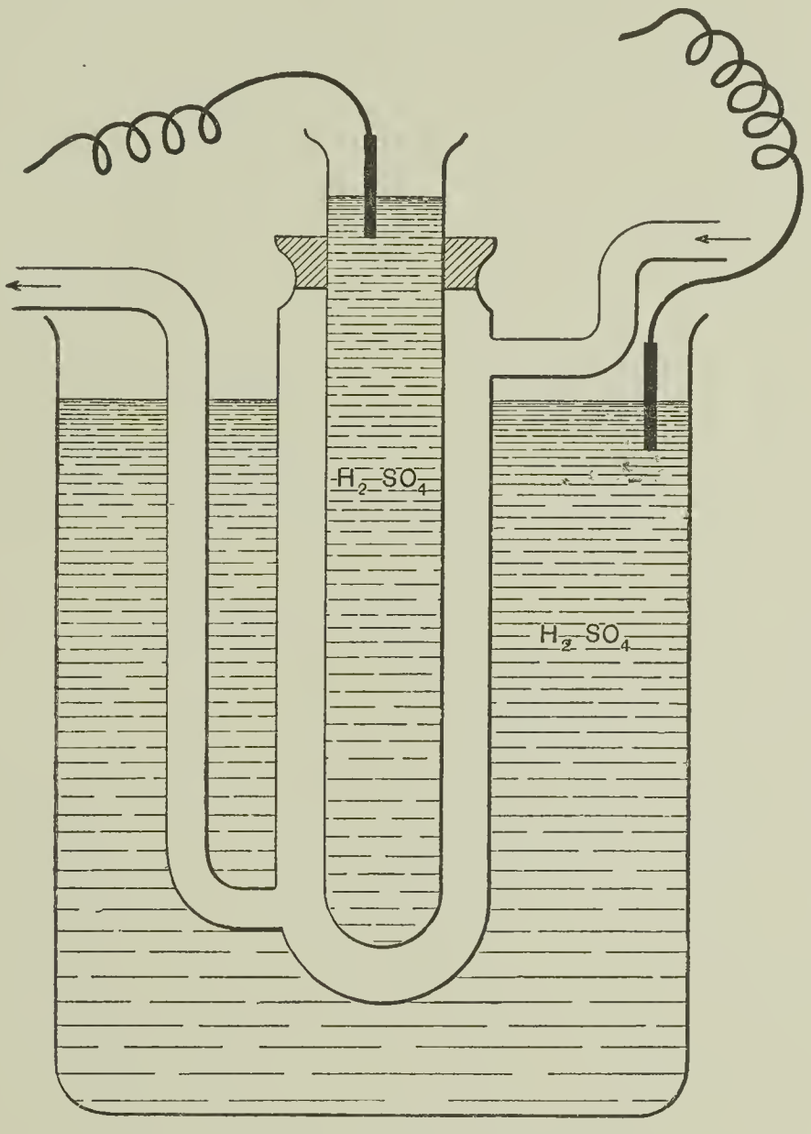

FIG. 1.—Berthelot Ozonizer.

transformer, is always a part of an ozonizer except in cases where induction coils or static machines furnish the electrical energy.

In order to understand the action of an ozonizer, it is necessary to first dwell upon the influence of voltage, heat and moisture on the generation of this gas and upon the relationship between yield and concentration.

The amount of ozone which can be generated in an ozonizer of the Berthelot type is theoretically in direct proportion to the wattage of the discharge per unit of air ozonized. This would be

true in practice if it were not for the destructive action of heat on ozone. There is a considerable amount of heat formed in the so-called cold or silent discharge and the heat thus generated increases, of course, as the square of the current of the discharge. In using a high wattage of electric discharge per unit of air ozonized, a condition which is necessary in order to obtain the high yields and concentrations required for industrial purposes, it is desirable to use as high a voltage and low a current as feasible. Most failures in ozone generators are due to insufficient understanding of this principle, the natural tendency of designers being to use as low a potential as possible. There is no good reason for employing low voltages, and it has been proven that, contrary to former belief, the formation of ozone is not limited to certain voltages or frequencies. It is only at about 8000 to 10,000 volts that the process of ozonization becomes economical, and apparatus employing voltages below that are hopelessly low in efficiency for all purposes where both high yields and concentrations are required. In former years, our limited knowledge of high potential transformers and other alternating-current machinery made it necessary to use low voltages, but at the present time, the design and manufacture of small and efficient apparatus of this kind affords no difficulties, and there is, therefore, no necessity of restricting the voltage employed. Voltages as high as 40,000 volts are now used, and the most successful ozonizers are those which employ high voltages.

The effect of heat on the formation of ozone is illustrated in the diagram shown in Fig. 2, which is taken from L. Gerard's treatise on ozone in the August number of the proceedings of the Société Belge d'Electriciens, 1909, from which you can see that the production rapidly diminishes as the temperature increases. After 80° C. it falls off still more rapidly, and at 270° C. it is 0. The importance of keeping the electrodes cool, as well as the air to be treated, can readily be grasped from this diagram. The very best-designed ozonizers still generate so much heat that for commercial yields and concentrations it becomes necessary to resort to artificial cooling of the electrodes or of the air to be ozonized. Some designers have even resorted to refrigeration of the air before ozonization and some very good results have been obtained thus, but it should be said that refrigeration is not necessary in small apparatus, if sufficiently high voltages are used,

although for low-voltage discharges it is perhaps the only means of obtaining anywhere near commercial yields.

The concentration of ozonized air is the amount of ozone expressed in grams contained on one cubic meter of air, and is a

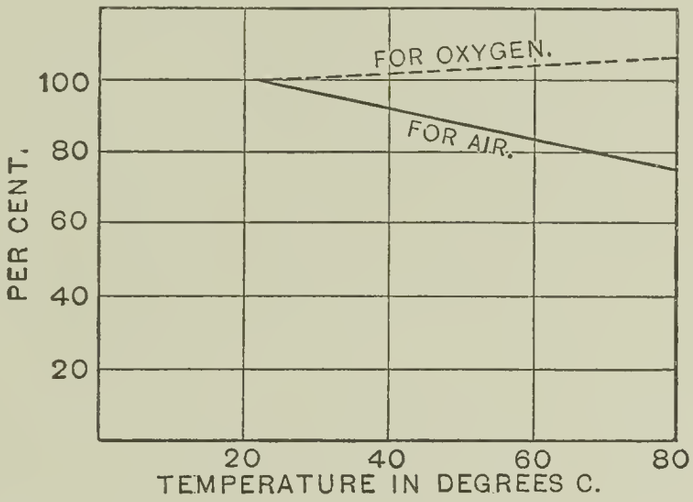

FIG. 2.—Relative Production of Ozone at Different Temperatures as Compared with 22° C.

very important factor in all processes in which ozone is used. The yield of an ozonizer is usually expressed by giving the amount of ozone generated in grams per kilowatt hour of electric energy consumed. The latter includes the transformer losses, but not

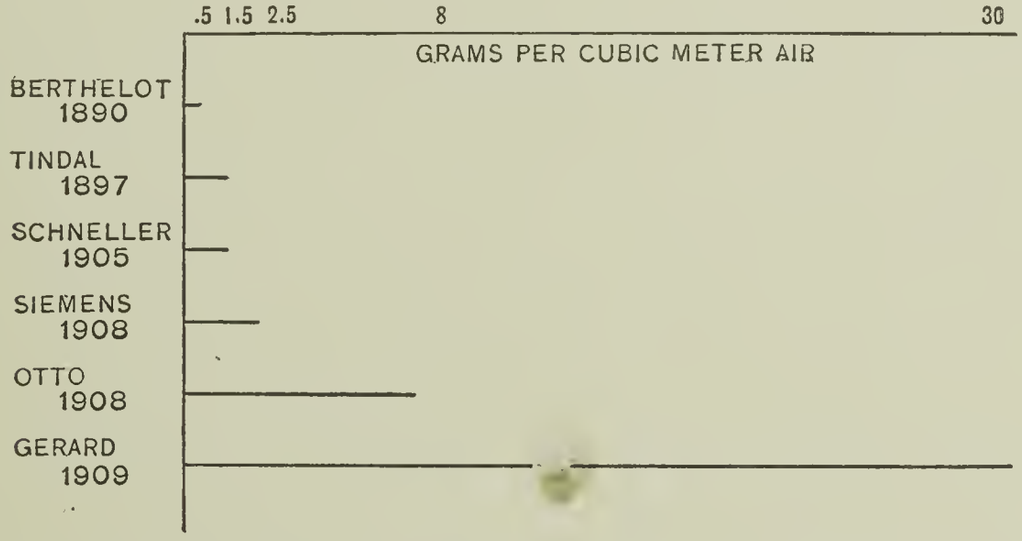

FIG. 3.—Concentrations of Ozone Obtained with Various Ozonizers.

that of other auxiliary apparatus. Much progress has been made during the last twenty years in both concentrations and yields obtained, as shown in Figs. 3 and 4, which are taken from Gerard's above noted treatise. You will notice that concentrations as high as 30 grams per cubic meter of air, which would correspond to

2 per cent by volume, and yields as high as 100 grams per kilowatt hour, have been obtained. Quite recently even higher yields have been achieved in an experimental plant built on the Steynis Refrigerating system, which is reported to have given never less than 105 grams and sometimes as high as 250 grams of ozone per kilowatt hour at a concentration of about 4 grams.

Unfortunately, an ozonizer is, in its action, similar to a storage battery, and it is, at the present time, impossible to obtain the highest concentration at the greatest efficiency. An increase in the concentration will bring with it a decrease in the yield, or vice versa. This is easily understood when the heating effect of the discharge is considered. In running an ozonizer at a high

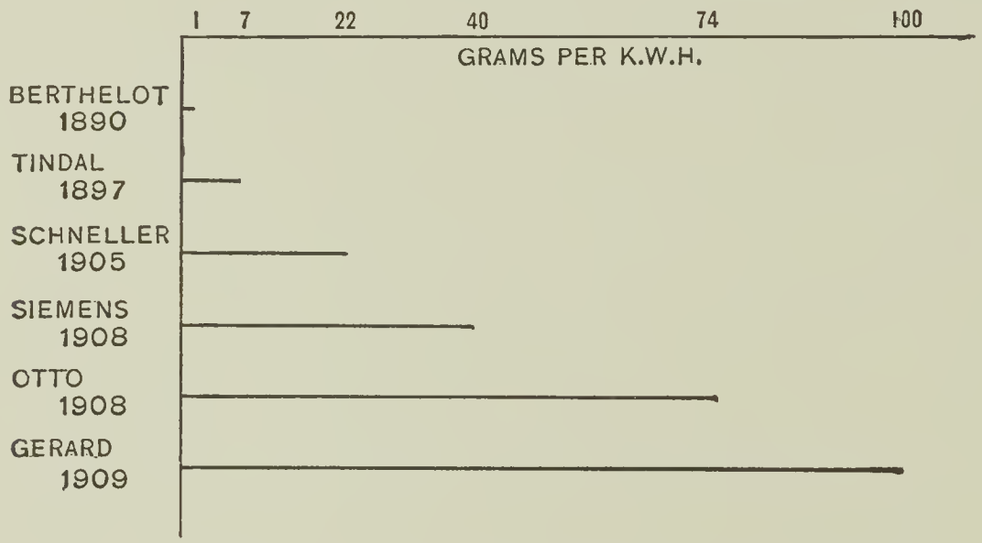

FIG. 4.—Yields of Ozone Obtained with Various Ozonizers.

concentration, the wattage of the electrical discharge per unit of air to be ozonized must be high, and this necessitates a slow rate of flow of the air to be ozonized or a high density of discharge per unit of electrode surface. Both these conditions favor excessive heating of the air during ozonization, and this, we have seen, is unfavorable to a large yield. On the other hand, in running an ozonizer at a high yield, the most effective cooling of the electrodes is necessary and can be best obtained by circulating through the electric glow a large volume of air, resulting, of course, in lowered concentration (see Fig. 5*). It is evident that this relation between concentration and yield, being due to the heating effect

* From Gerard's treatise on Ozone, Proceedings of the Société Belge d' Electriciens, August, 1909.

of the discharge, will be all the more favorable from a commercial standpoint, the higher the voltage employed.

The density of discharge per unit electrode surface is a factor depending largely on the design of the apparatus and on the voltage and rate of flow of the air through the apparatus. As a general

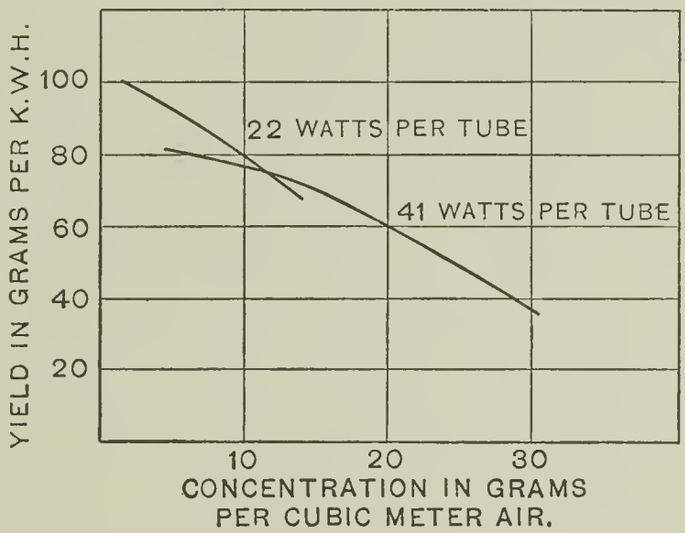

FIG. 5.—Relation between Yield and Concentration Obtained by Gerard Ozonizer.

rule it is considered good practice not to exceed .4 watt per square centimeter electrode surface.

The effect of humidity of the atmosphere on the production of ozone is shown in Fig. 6*. The presence in the air to be ozonized

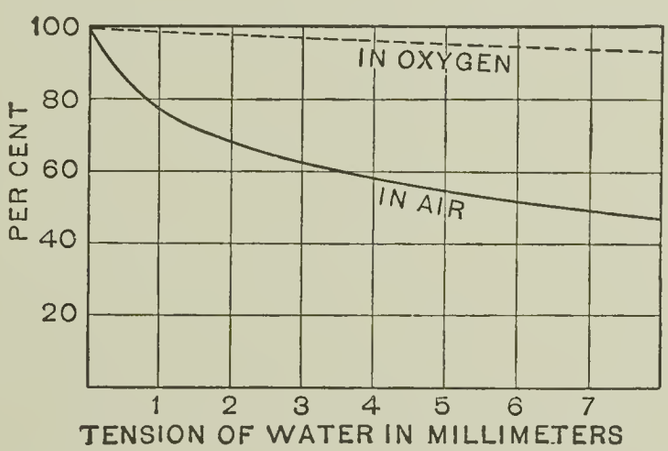

FIG. 6.—Relative Production of Ozone as Influenced by Humidity.

of water vapor so greatly reduces the production of ozone that for all commercial concentrations except for ventilation, it is necessary to dry the air before ozonizing it. This practice is

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* From Gerard's treatise on Ozone, Proceedings of the Société Belge d' Electriciens, August, 1909.

followed in almost all instances and is usually accomplished by passing the air through a tank containing lime before passing it through the ozonizer, or in large plants, by refrigeration.

It must be understood that where very low concentrations only are required, such as for ventilating purposes, it is usually unnecessary to employ artificial cooling or drying of the air. In a well-designed apparatus of this kind, sufficient cooling is accomplished by passing a large volume of air through the air gap of the ozonizer.

In subjecting air or oxygen to the effect of electric stresses, it is well known that some other products are formed besides ozone. If water vapor is present in the air or oxygen, there may be some hydrogen peroxide formed. However, the drying of the air before ozonization does away with this possibility. In small ozonizers used for ventilating purposes in which it is not customary to dry the air, the amount of hydrogen peroxide formed is so small and the dilution so great that its presence can be disregarded, especially considering the great similarity in action between hydrogen peroxide and oxygen.

Besides hydrogen peroxide, there is always formed a more or less small amount of the oxides of nitrogen. Their presence in the ozonized air is highly undesirable and should be carefully avoided. The formation of these oxides is favored by heat, sparks, dust and dirt, and it is therefore important in the design and construction of ozonizers not only to provide sufficient cooling, but also to prevent the formation of disruptive discharges or sparks in place of the cold or silent discharge during the operation of the apparatus. As formation of sparks is favored by the accumulation of dust and dirt in the air space, in the design of ozonizers, it is very important that particular attention be paid to the necessity of keeping the air space clean and free from any accumulation of dust and dirt. The amount of nitrous oxides formed is, as a rule, very small. In well-designed ozonizers there should not be more than 1 or 2 per cent of nitrous oxides formed, figured on the amount of ozone generated. In poorly designed apparatus the amount of nitrous oxides formed may run up to 5 or 10 times this amount.

During ozonization the air to be treated must be kept in positive motion; a fan, blower or air pump is, therefore, a necessary accessory of every well-designed ozonizer.

In regard to the quantitative determination of ozone, it should

be said that most of the figures which we find in the literature up to about ten years ago are unreliable, owing to defective methods. At the present time the determination of ozone in the higher concentrations does not afford any difficulties, but in low concentrations, such as in the atmospheric air, accurate determinations are even now impossible. For industrial use, the method now considered standard is the absorption of ozone by means of a *neutral* potassium iodode solution. The iodine set free by the ozone is titrated after acidifying in the regular way by means of sodium thiosulphite and starch. The hydrogen peroxide which may be formed in the presence of water vapor in the air to be ozonized, is best eliminated by passing the ozonized air over finely divided chromic acid crystals before passing it through potassium iodide solution. For very small concentrations, manganese chloride paper in conjunction with Guajak tincture of thallium suboxide, as recommended by Engler and Wild, and also the well-known tetra-base paper, are giving fair comparative results. They are not, however, accurate enough for determining quantitatively the amount of ozone in atmospheric air.

It is not the intention of this paper to go into details as regards the various apparatus for producing ozone, as there are a number of treatises available where this information can be obtained, for example, the book on Ozone, by Henry Lecoux, the paper on Ozone, by Léon Gerard in the August number of the Proceedings of the Société Belge d'Electriciens, 1909, the various papers by Ehrlwein, F. Fischer, Warburg and many others, some of which I mention in this paper. Most plants where a large amount of ozone is consumed have been designed specially to suit the conditions of one particular problem; therefore, there is no such thing as standardization in this line and the number of designs so far is nearly as great as the number of installations.

The first ozonizer constructed to meet with some success was that of Berthelot in 1899, a sketch of which was given in Fig. 1. The general principle of this apparatus has not been changed to any great extent by later investigators, although changes in details of construction and the progress in our knowledge of alternating-current machinery made it possible for later designers to greatly increase its efficiency. The best known of the ozonizers of recent date working on the Berthelot principle is that designed by the engineers of the Siemens & Halske Co., whose comprehensive

investigations and publications have done much to bring the subject to the attention of the technical world. A still more recent

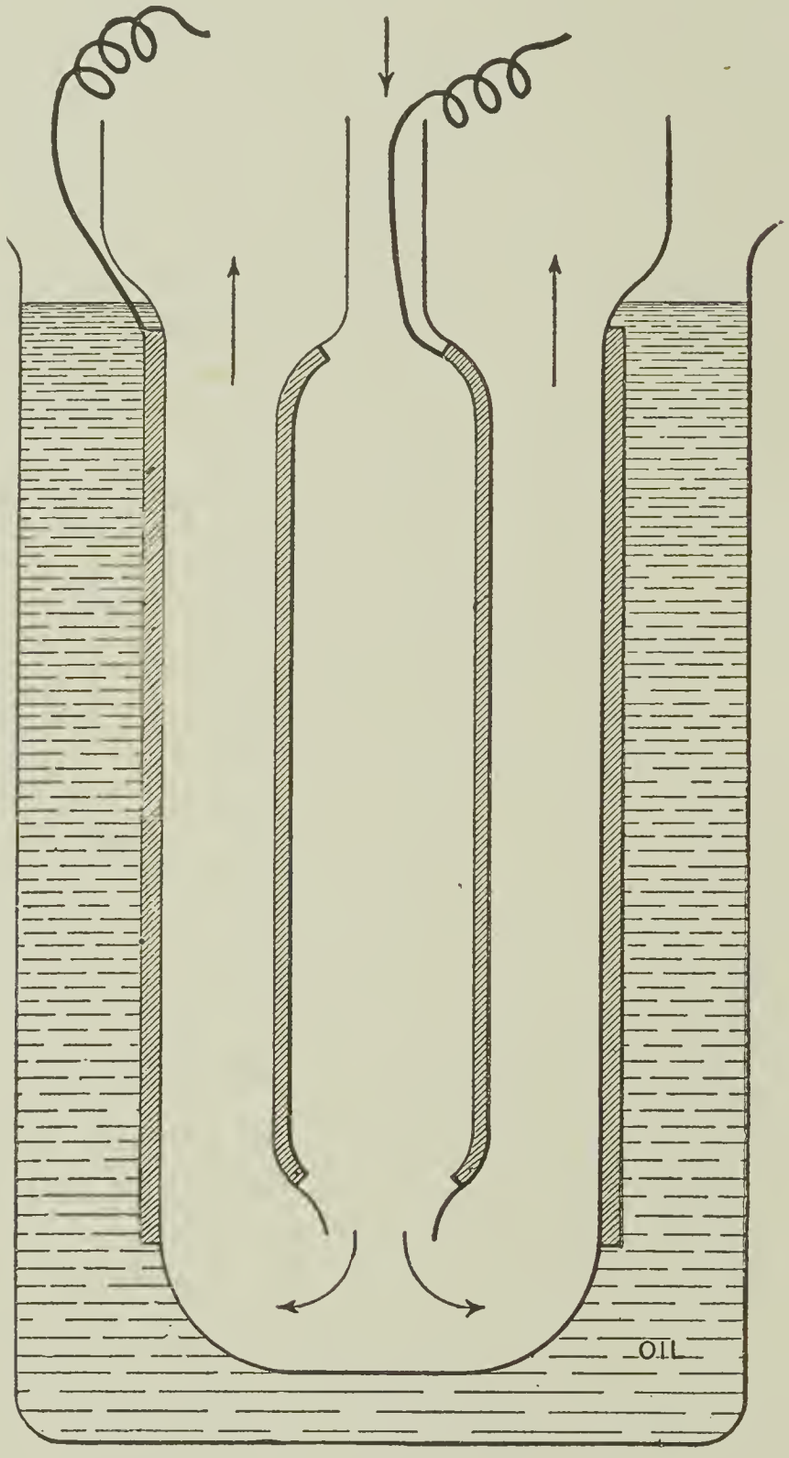

FIG. 7.—Gerard Ozonizer.

design and one which has achieved considerable success is that of Gerard, a sketch of which is given in Fig. 7.

Industrial Applications

The industrial application of ozone has been delayed greatly in the past by unusual requirements set up by the manufacturers of such apparatus in regard to the nature of the electric current supply: Until comparatively recently it was necessary to use static machines or induction coils run by primary batteries in order to obtain a discharge of the characteristics recommended by the manufacturers, and even to-day the use of interrupted direct current or of alternating current of frequencies not met with in practice, are prescribed for some apparatus. It is no wonder that under such conditions the use of ozonizers has made slow progress, but fortunately it has been found that the regular alternating current of commercial frequencies can be used just as well and in most cases to better advantage than many special forms of electrical energy recommended in the past. Thus, it is now possible to purchase ozonizers operating from alternating lighting circuits without further electrical apparatus than a transformer; in places where direct current only is available, we can convert it into an alternating current of the desired frequency by means of a small and inexpensive converter, several types of which are now on the market for that purpose. Small ozonizers for ventilating purposes are even made so complete and compact that they can be connected to any electric light socket by means of a screw plug and cord, and they can be obtained for any commercial voltage, either alternating or direct current.

1. Water Purification. The subject of water purification by means of ozone has been so extensively treated and discussed in the past that it is not necessary to go into details. The success of this method of water purification has been definitely proven, and it has been found that in large installations it is not only safer and more effective, but also cheaper than quartz filtration, and requires less space. Those specially interested are referred to a recent treatise on this subject in the *Engineering News* of April 28, 1910. Large installations for water purification are, as a rule, designed specially to suit the requirements of one particular problem, therefore the subject cannot well be treated generally with other uses of ozone.

The bactericidal properties of ozone since having been studied and proven by Froehlich and Ohlmueller, have perhaps been more

frequently investigated than any other of its properties, and the fact that bacteriologists like Pasteur, Roux and Koch have indorsed them, has left no further doubt in the minds of the most skeptical persons. Ozone oxidizes the impurities in water and renders them harmless; it discolors dirty water and still leaves no compounds harmful to the health or disagreeable to the taste. This purification is accompanied by a distinct phosphorescence of the water. In cases where muddy appearance is largely due to substances of mineral origin it is customary to partially clear the water by means of a pressure filter before ozonization. Owing to the great variation in the composition and appearance of a water at different times it is customary to use about twice as much ozone as is found necessary to thoroughly purify an average sample of the water in the laboratory. The concentrations used for water purification are high and range from 5 to 12 grams of ozone per cubic meter of air, according to the quality of water. The amount of ozone required for purifying 1 cubic meter of water also varies greatly according to the quality of the water, but may be given as from .5 gram to 10 grams ozone per cubic meter of water. The above figures represent about the limits ever used for purifying water of any kind.

Owing to the low solubility of ozone in water (it is given as from 5 to 10 parts in 1000 parts water) a very intimate contact between ozonized air and water is necessary, and this is usually accomplished in towers constructed on the principle of the absorbing tower or by sprays and injectors.

There seems to be no close agreement between the figures published about the cost of operation of the water purifying plants now in operation, but a perusal of the data available would show the cost of purifying, including interest, depreciation and maintenance, to be from .1 to .4 cent per cubic meter or from $3.80 to $15.00 per million gallons, according to the quality of the water to be purified.

2. Ventilation. One of the newest fields for the application of ozone is in the ventilation of rooms and buildings. Good ventilation is being appreciated more and more because of the physical comfort which it affords, as well as because of its therapeutic and hygienic importance. In all modern buildings, theaters, passenger boats, hotels, etc., a ventilating system is an important part of the equipment and even in places the very name of which

is associated with bad air, such as street cars, sleeping cars, tunnels, etc., the feasibility of supplying good air is being seriously studied. Up to the present time the problems of ventilation have mostly been categorically solved by heating or cooling the air to the proper temperature, and in some few cases by filtering it through a spray of water or a solid filter. Recently, however, the demand has arisen to improve the air by charging it with ozone to a concentration corresponding to the normal percentage found in places noted for the purity and freshness of the atmosphere.

It has been found and demonstrated that the presence of ozone in air in small quantities has a beneficial physiological action. It gives a pleasant and cheerful effect which is not noticed in air free from ozone. It stimulates the appetite and produces sound sleep. Its action has been compared with the effect of moderate physical exercise upon the general condition of body and mind. Physical examinations of people working in places which are supplied with poor air have disclosed a decided gain in weight and chest measure after ozonizing their air supply for some weeks.

Ozone is now generally considered a necessary constituent of good atmospheric air. It is well known that the air in cities and in all well-populated places is depleted of or entirely free from ozone, owing to the abundance of oxidizable organic matter in the air of such districts. The absence of such floating matter in the open country and especially in the mountains and on the sea is held accountable for the presence of ozone and also for the general healthfulness at such places.

The question how to improve the air in cities and in closed places where people congregate, is a problem which is just now receiving some serious attention for the reason that by far the largest percentage of deaths among the adults in cities is due to diseases resulting from bad air. Perhaps the greatest destination of ozonizers is in this field of improving general air conditions, for the powerful oxidizing properties of ozone can be put to a particularly practical use for purifying and deodorizing air. Indeed, it has been found that foul gases, organic matter floating in the air, offensive odors and everything else which is commonly called air sewage, is thoroughly oxidized and destroyed by ozone. It is well known that this matter, which we have defined as air sewage, is a specially attractive ground for bacteria, miasmata

and other animal and plant life of the lowest order, which thrive in cities and congested districts. In such small concentrations as ozone is employed in ventilation, the destruction of this air sewage is probably its beneficial action, rather than the direct destruction of bacteria, which has often been accredited to it. It has not been proven that ozone, when diluted to the extent of one part in one million parts of air, can act directly as a bactericide, but it is an established fact that even in such dilutions it acts as a deodorizer and destroyer of the food and favorite surroundings

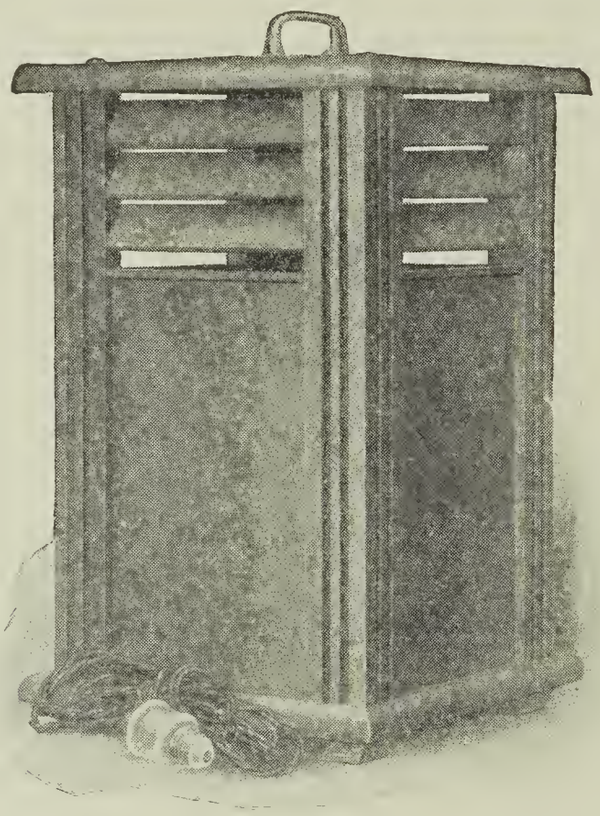

FIG. 8.—"Vohr" Ozonizer for Ventilation, Home Machine.

of the bacteria, thus depriving them of the conditions favorable to their propagation. So energetic is the action of ozone on such undesirable matter that the presence in the air of ozone can be taken as an indication of the purity of the air and its freedom from air sewage.

Ozonizers made specially for ventilating purposes are now on the market and are made either of portable or stationary type. There are several systems manufactured in this country and in Europe, the latest one on the domestic market being the "Vohr" ozonizer, cuts of which are shown in Figs. 8 and 9. It is made either for alternating or direct current and in various sizes to suit the requirements of the air space to be taken care of, and is portable,

self-contained and adjustable. The general plan of these machines is to draw in the air to be ozonized and subject it to electrical stresses by passing it through an air gap in which a silent electric discharge takes place and then discharge it immediately to the outside air.

The cost of operation of such ozonizers, is, as a rule, very low, for example for the Vohr apparatus, the consumption of electric current is about 65 watts, for circulating and ozonizing 10,000 to 15,000 cu.ft. of air per hour. The concentration is, of course,

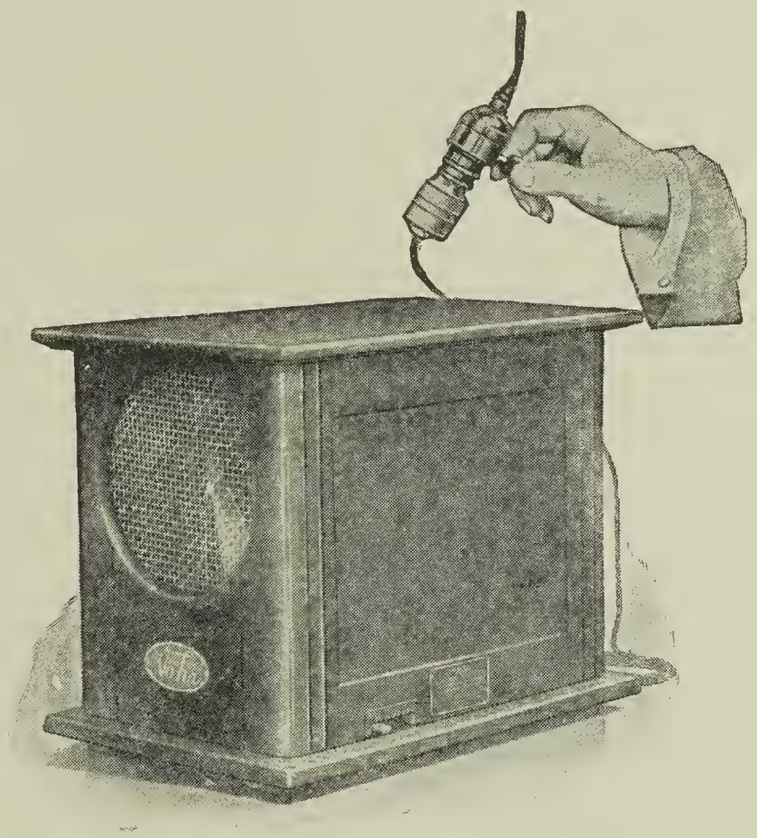

FIG. 9.—"Vohr" Ozonizer for Ventilation, Office Machine.

very small and does not greatly exceed that found in the best outdoor atmosphere. It should be mentioned here that a common mistake made in the installation of ozonizers for ventilating purposes is that too high a concentration of ozone for breathing purposes is produced. An excess of ozone in the air is unpleasant to many people, and while it cannot be considered dangerous, still there is a possibility of producing temporary discomfort. The concentration best adapted for breathing purposes has been a subject of much discussion, it has been variously given as from .0001 to .5 gram per cubic meter air. For direct breathing a concentration of .5 gram is altogether too high and would be extremely

unpleasant even for only a few minutes. The figure that has been best agreed upon is a concentration somewhat higher than the natural concentration in the atmospheric air, say about 0.3 part ozone in 1,000,000 parts air or about 0.5 milligram ozone per cubic meter of air. A popular rule for the use of such ozonizers is that there should be enough ozone in the air that its odor is just perceivable at all times. Ozonizers giving higher concentrations than .01 gram cannot be considered safe and in using such apparatus particular pains must be taken to have the concentration properly reduced by diffusion.

While one is inclined to regard these ozonizers skeptically at first, still their benefits in every-day life have been proven and demonstrated in many cases by medical authorities. As a general means for improving the air and as a deodorizer, ozonized air has found no rivals and is bound to come into very general use. Numerous houses, hotels, schools, theaters and restaurants, and especially the leading establishments of this kind abroad, have been equipped with them, and the reports on their effectiveness are generally very gratifying.

3. Miscellaneous Applications. The industrial applications other than for water purification and ventilation are manifold. What I have said about manufacture, ventilation and water purification will give you a fair idea of the possibilities along different lines, and I have perhaps treated these two applications at greater length than their relation to chemical engineering demands.

For reasons previously explained the use of ozone as an oxidizing agent in purely chemical industries has not yet been recognized to any great extent. Since, however, it has been possible to obtain concentrations up to 30 grams of ozone per cubic meter of air, which corresponds to 2 per cent by volume, by means of a comparatively simple apparatus, many possibilities present themselves of using ozonized air for oxidization processes, especially in cases where it is desirable that no foreign element be introduced into the reaction.

By virtue of its gaseous condition and its powerful oxidizing qualities, ozone is an ideal gas for sterlizing and disinfecting purposes. Like all strong oxidizers, it is destructive to animal and vegetable life of the lowest order, while to animals of higher order and to human beings it is comparatively harmless. There are

several installations that are being experimented with in order to test the efficiency of ozone as a disinfectant, one being, for example, at the Quarantine Station at New York, and another one at the Pittsburg Homeopathic Hospital. Judging from the results obtained in sterilizing rooms, bandages, laundry and surgical instruments in hospitals, it is believed that ozone will ultimately supplant formaldehyde in disinfecting rooms and buildings. The concentration used for disinfecting and sterilizing purposes is, of course, rather high, and should not be less than 5 grams and preferably as high as 10 grams per cubic meter of air. The sterilization of sewage is a problem which we will be confronted with in the near future in order to avoid the increasing pollution of our rivers and lakes, and will be a very fruitful subject for ozone some day, and one in which it will have to show its full worth. Very considerable concentrations are required for this purpose and 10 to 20 grams per cubic meter air will be none too high.

The uses of ozonized air in medicine are many, but it is not within the scope of this paper to discuss them. Let it be mentioned that it has been used successfully for inhalation in cases of anemia, nervousness, insomnia and pulmonary diseases or for local application in the treatment of skin diseases, cancerous growths in obstetrics, etc.

One of the largest fields for ozone in the future is the preservation of food products. Experiments have shown that milk, cream and butter can be completely sterilized and, therefore, kept from fermentation and souring for a considerable period of time; eggs when stored in an atmosphere of ozonized air will keep for months without apparent change; the effect on fruit is still more striking, as ozone prevents the molding, which starts on the outside of the skin. In storing meat products, it has been found that refrigeration is greatly helped if the air in the storage rooms is ozonized, and that the temperature of the refrigerating room or chamber can be considerably higher in the presence of ozonized air than under ordinary conditions. As a preservative, ozone is also destined to meet with considerable use, supplanting drugs, sugar and sterilization by heat.

The apparatus necessary in the applications of ozone is very simple. It is illustrated in Fig. 10, and consists of the drying bottle or tank, containing sulphuric acid, calcium chloride or lime,

the fan, blower or air pump necessary to circulate the air through the ozonizer, and the ozonizer proper, containing the step-up transformer. For experimental purposes it is usual to have a testing outfit in connection with the apparatus, consisting of an absorbing bottle for the potassium iodide solution, an aspirator to draw in from the main tube and measure the volume of air passing through the absorbing solution, and a gas meter in the main line by means of which the total volume of air ozonized can be measured.

Considerable success has been achieved by the use of ozonized air in order to prevent the growth of parasites, as for example, in the storage of flour and flour products, to prevent molding. It has also been applied in many cases, especially in England and Belgium,

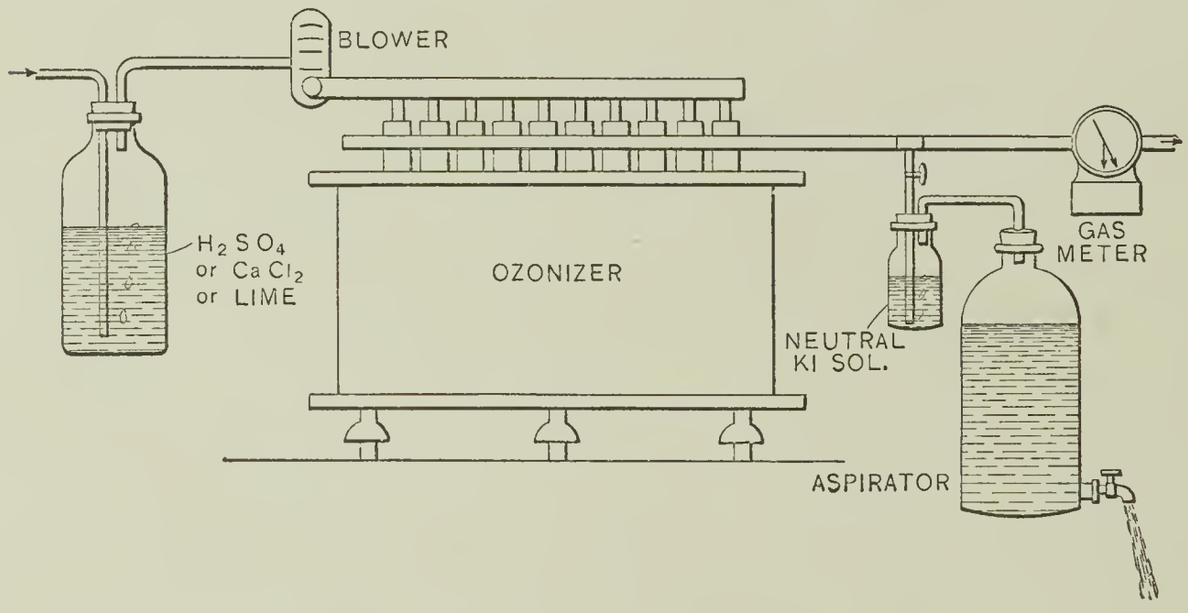

FIG. 10.

to the fermenting cellars of breweries, where it prevents the growth of parasites, and still has no retarding effect on the fermenting process. The number of living bacteria in these cellars is said to be thereby also greatly reduced, and it is generally found that those which are not directly killed are not capable of reproduction. Concentrations of about 0.5 gram ozone per cubic meter air are usually adapted for this purpose. Besides this, a number of breweries have adopted the ozone system for the purification of their water supply.

In the case of the manufacture of wines and liquors, ozone is being used to a large extent in France for the purpose of destroying the empyreumatical odor and oxidizing the fusel oils in products which have not been sufficiently aged. The action of ozone

in this case is said to be identical to the action of ageing, and it is reported that wines and liquors are produced in France in from 3 to 12 months which cannot be distinguished from similar products which have been aging for from 2 to 10 years. Ozonized air is also largely used for sterilizing casks and other implements used by producers of wines and liquors.

The bleaching and deodorizing properties of ozone were recognized early and are now being utilized to a considerable extent in the case of fats and greases, and oils of mineral, vegetable or animal origin. Vegetable oils, for example, are not only bleached and discolored, but also thickened; and in the case of animal products like tallow grease and fats, ozone has been found a valuable means of improving appearance and quality. Rancid and other offensive odors can be entirely removed and it is possible in this way to considerably reduce the amount of waste in such materials.

In the case of sugars, as well as flour and starch, ozonized air has been found to accomplish bleaching very satisfactorily. Its bleaching effect is superior to even that of chlorine, and is all the more striking as it not only bleaches, but destroys diseased parts and kills parasites which feed upon such products. There are hundreds of other applications of ozone in bleaching, such as, for example, delicate processes like the bleaching of ostrich feathers and fine fabrics. In ordinary laundry work ozone surpasses the effect of bleaching chemicals and has the additional advantage of sterilizing the fabrics without injuring the strength and flexibility of the fiber, such as the bleaching agents generally used for this purpose do. The bleaching of wood pulp is also one of the future fields for ozone. As to the concentration of ozonized air which is employed for bleaching I would say that it should be as high as possible, and an average of 8 grams per cubic meter air is none too high for this purpose.

There are a number of purely chemical uses for ozone, and it is safe to predict that as an oxidizing agent it will come into much more general use in chemical manufacturing and research work than it is at present. As an example, I remind you of the use of ozone in the production of artificial camphor, in the synthesis of rubber, and the large field it will have in the future in the manufacture of perfumes.

The metallurgical industry has started to make quite an exten-

sive use of ozone in the cyanide process of extracting gold and it is claimed that the yield has been increased from 60 to over 90 per cent by means of ozonized air.

A field for ozone which has not as yet been exploited, but which is bound to become important in the future, is the sterilization of the water used for refrigeration. Ice made from water which has previously been purified with ozone is perfectly clear and sterile and will ultimately fill a long-felt want in this direction.

As a deodorizer, there is no substance which can at all equal ozone, and it is possible, by means of it, to remove in an incredibly short time offensive odors in storage rooms, glue and leather factories, and in other establishments noted for their disagreeable odors.

The outline which I have given you of the accomplishments and possibilities in this new field should serve the purpose of calling your attention to and awakening your interest in a product which, for general usefulness, is surpassed by very few of the thousands of substances known to chemistry. There is no special branch of the chemical industry where ozone cannot, in some manner or other, fill a want, and I believe that there are few, if any, members of this Institute present who will not find it to the interest of the industry they represent to further investigate the subject.

Discussion

President McKenna:

I can support Dr. Linder in what he says about the value of the application of ozone in the refrigerating industry, because I have lately had the opportunity to witness the enthusiasm of a gentleman interested in that business for this use of ozone, which they had tried on a large scale. Its value lies, apparently, in its "bactericidal" action. They are able to keep meat and foodstuffs very fresh in the room. The water which they freeze for ice is also treated in this way.

Dr. Frerichs:

Will you give us an idea of the general size of the apparatus for ozonizing a certain amount of air?

Dr. Linder:

The apparatus which I have shown in the sketch here for industrial application, of course can be made in any size desired.

It consists of units of tubes. Each tube is a unit, and you can combine as many of these tubes as you wish in one apparatus. The usual practice is to put about 10 tubes in one tank. The tubes are about two to three feet long and three and a half inches in diameter, and they are immersed in tanks filled with oil. The tank containing the ten tubes is a standard apparatus. If a higher concentration, or greater amount of ozone is required, all you have to do to is to take several tanks and connect them up in parallel. You will understand that the air passes through only one tube, and is then discharged from the apparatus. It never passes through two or more tubes in series, but you can connect up any number of tanks or tubes in parallel, in order to get the necessary concentration.

Dr. Frerichs:

How much ozonized air can you make with one unit?

Dr. Linder:

One unit produces an average of about 20 cu.ft. of ozonized air per hour. If you want 40 cu.ft. you take two tubes, and so on. Now you can, of course, adjust the rate of flow of air through the apparatus to any figure you want; you can cut it down to 10 cu.ft., or increase it to 400, and you will thereby be cutting down or increasing your concentration. By increasing the rate of flow you decrease the concentration. By varying the amount of air, you can get any concentration or yield your desire.

Dr. Grosvenor:

Approximately what concentration corresponds to 60 cu.ft.?

Dr. Linder:

That corresponds to about 6 to 8 grams ozone per cubic meter of air.

Dr. Frerichs:

Why is the air not run through the tubes in series?

Dr. Linder:

You can run the air through the tubes in series, but your efficiency will be decreased very much by doing so. The preferable thing to do is to reduce your air circulation through the apparatus, and use more tubes.

Dr. GROSVENOR:

What is the consumption of energy per tube for such yields as are required?

Dr. LINDER:

That would be in the neighborhood of 50 watts. You can figure it out very easily from the air circulation with the figures I have given—60 cu.ft. per hour, and taking a concentration of 8 grams per cubic meter.

Dr. GROSVENOR:

Including the ozonizer, and the necessary transformers, etc., but not the conduits for delivering the air, what would be the approximate cost of such an installation?

Dr. LINDER:

A single-tube installation would probably cost in the neighborhood of $150 to $200.

Dr. GROSVENOR:

For a single tube, but not for a single unit?

Dr. LINDER:

No. One tube is a unit.

Dr. GROSVENOR:

Then a single tube would give you 2 cu.ft. of air per hour?

Dr. LINDER:

No. The figures I have given you are for one single tube.

Dr. GROSVENOR:

And your power then was for a single tube also?

Dr. LINDER:

All the figures I have given are for a single tube. A large item of the cost is for the blower.

Dr. SADTLER:

Has anything definite been found with regard to removing the rancidity of oil?

Dr. LINDER:

The method is now used quite extensively in Chicago. Of course it is still in an experimental stage, and they do not, perhaps, want to give out definite figures, but they have been very successful.

Dr. SADTLER:

Does the method depend upon the oxidation of the fatty acid?

Dr. LINDER:

It must be something of that kind. Just what the process is, I do not know. The deodorization of air must be a similar process.

Dr. SADTLER:

Then the ozone does not facilitate the splitting up of the ester and the liberating of the fatty acids. In other words, the rancidity is not increased, but the acid is oxidized and thereby removed. I was very fearful that they were increasing the acidity of the oil. In the matter of the aging of whiskey, there is a great deal of mystery in the popular mind. It has been shown by a chemist of the Bureau at Washington that the fusel oil is not destroyed, but more ester is produced and the fusel oil obscured—masked. I doubt very much whether ozone will kill the fusel oil—oxidize it. It probably does what storing in charred barrels would do—facilitates esterifications.

Dr. FRERICHS:

About sixteen years ago extensive experiments were made by Siemens & Halske, for the purpose of using ozone for the aging of woods for musical instruments, and they were hopeful that they would be able to prepare woods in a very short time for violins of the same value as the old instruments, and also to prepare wood for sounding boards for pianos.

Dr. LINDER:

I do not know how it came out. The experiments were made a long time ago. I remember reading about them, and rather think the results were negative.

Dr. FRERICHS:

The experiments were made in the middle 90's.

CHANGES IN INDUSTRIAL CHEMISTRY CAUSED BY ELECTRICITY

Or the New Industrial Chemistry

By EDWARD R. TAYLOR, Penn Yan, N. Y.

Read at the Niagara Falls Meeting, June 22, 1910

This paper is presented to the Institute not to convey information to ourselves, but to call attention to the importance of our making known to people in general some things that from our vantage ground we see sooner than do some others, and which should be provided with cheap power by the Nation and the several States for their development.

The production of the aluminum alloys by the pioneer work of the Cowles Brothers, quickly followed by the production of pure aluminum by Dr. Chas. M. Hall, and the use of that metal in the Thermit process of Goldschmidt, gave us quickly not only aluminum but indirectly chromium, molybdenum, titanium, tantalum, tungsten, and also a host of ferro alloys of these metals and many others such as ferro-aluminum, ferro-boron, ferro-manganese, ferro-molybdenum, ferro-nickel, ferro-silicon, ferro-silicon aluminum and ferro-uranium, all of which are having increased usefulness, especially as reducing agents.

Hall at one stroke changed the manufacture of aluminum from the chemical to the electrical method, thus destroying the commercial value of the great advance of Castner over the intrepid De Ville in the chemical production of aluminum. Not to be outdone and as a compensation to the then blasted hopes of his shareholders, the intrepid and honorable Castner evolved his electrical transformation of the alkali trade, which trade every chemist recognizes as the foundation of industrial chemistry. The world can never know its loss from the untimely death of that brilliant man.

Up to the time of the Solvay process, the alkali trade had never obtained a foothold in this country, nor could it, under the old Le Blanc process with its almost endless series of waste products that could only be utilized by long established firms of large means and experience.

I need only hint at the costly and disagreeable features of this process, but must say enough to lead our minds back sufficiently to realize into what a broad opening we ourselves have come in this day. It is not too much to say that, for its day, the work of Le Blanc was quite as brilliant and quite as creditable as the work of Castner. Indeed the industry was resting at ease and in comfortable security, intrenched in a labyrinth of indirections, wealth and experience. Improve the grand Le Blanc process, except in some minor details which was done from time to time, from within? No, never! They said it was here to stay and acted accordingly. Strange to say the change came not from within but from without. A young man—a student—with little or no industrial experience, thought and worked, and the alkali world awoke to a new day.

Indirection is of the past. The mere mention of the names salt cake, black ash, tank waste, tells to the chemist the story of the chemical disorder and smoking chimneys of the past. With the direct electrochemical method we have at once chlorine and soda, both free and ready for use; practically no waste product, no side issue, no smoking chimney, no slovenly work; just caustic soda (or soda ash if required) and chlorine, both in a state of remarkable purity and all ready for their highest use; soda ready to use at once in solution or shipped as a solid; chlorine ready to use at once, or liquified and shipped in little tanks, big tanks or in tank cars; no lime to add weight or requiring acid to decompose, making another waste and harmful residue in treated goods.

In reality the slowness of this coming is all the more remarkable in view of the fact that the electrical decomposition of chloride of sodium and the separation of caustic soda and chlorine without the intervention of waste products was an accomplished fact in the laboratory of Michael Faraday. This great realization had to wait the development of the gigantic dynamo, the embryo of which was in the same laboratory of that mighty

man,* who will go down into history as the greatest discovery of the mighty Davy.

The world little appreciates as it should the quiet work of the analytical and research chemists and physicists who have in these many years laid foundations on which we are building superstructures that are now startling the world by their brilliancy and utility. How few people know that a drop or a grain may mean to a chemist as much as a ton to some others.

The marvelous and interesting electrical separations and quantitative determinations of Dr. Edgar F. Smith, of the University of Pennsylvania, are laying a definite foundation for some future industries in the electrochemical world, that we shall do well to study with reference thereto. It is true that it is a long distance from the work of the laboratory to the established industry, but it is none the less true that the laboratory may and does when properly employed plainly indicate the direction of success or failure. Analytical chemistry has always been the best pointer for the manufacturing chemist. The thesis of Herbert H. Dow led to the cleaning up of the slovenly bromine manufacture, and out of the development has come the Dow Chemical Co., which, with the aid of the laboratory work of Dr. A. W. Smith, has also developed their extensive manufacture of chlorine, chloroform and tetrachloride of carbon, all based on electrochemical processes with large consumption of power.

I am free to say that on leaving the scientific school, chlorine in its possible utilities possessed for me a most fascinating interest, and it is a great gratification to me to see it now coming into its own.

Among other large industries in this department may be mentioned the Castner-Kellner Co., the outgrowth of the work of Castner before referred to, the Funding and Development Co. of Niagara Falls, now the Hooker Chemical Co. (the destruction of whose plant by fire we all lament), who are also making their decomposition cells available wherever wanted all over the world, and the Pennsylvania Salt Co. All of these companies are doing a large business in chlorine and soda products.

For years bleaching powder has been transported across seas

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* Davy was once asked what was his greatest discovery to which he replied, "Michael Faraday."

and half way across continents merely to furnish chlorine to extract precious metals from ores, while within near reach of those industries or mines are water powers from which electricity could be wired to release this valuable agent on the spot, and the time of doing this is near at hand.

Not less interesting are the small electrolizers furnished by the National Laundry and Machine Co. of Dayton, O., which enables every laundry, knitting mill or other small industry needing a bleaching agent, to install a small or large electrolizer, make an attachment to the town electrical supply, and produce its own chlorine just as required. The use of these electrolizers may even be extended to the purification of water supply, disinfection of sewage, chlorination of products, oxidation of metals, and a multitude of other uses now in sight and yet to come. How much easier to wire electricity than transport bleaching powder.

Even more interesting and closely in line with the above is the Vohr Electric Ozonizer, manufactured by the Standard Electric-Utilities Co. of Chicago, Ill., and placed on the market for use in private houses at a cost of less than one hundred dollars, so that the air in our private homes may be purified and deprived of all harmful germs, the electric attachment being to the ordinary electric light socket, and the cost to run the same as an incandescent lamp. Who shall estimate the value of this contribution to the new civilization that is upon us, and the prolongation of human life and happiness that shall result therefrom?

Not less marvelous are the other developments to which in point of time we now naturally come. The development of absolutely new industries by this agency has been the marvel of marvels. Willson applied the current at high temperature to a mixture of lime and coke, and out came calcium carbide. Nobody knew what it was good for. Then he went to work to find a use for it, and now there are seventy establishments in different parts of the world making this product, producing about 200,000 tons per year, and absorbing about 250,000 horsepower with the employment of 6000 men for its accomplishment. The acetylene light and oxy-acetylene welding only need to be mentioned to lead us to apprehend the present state of this important industry.

The production of calcium cyanamide from calcium carbide is now an established industry, fixing atmospheric nitrogen by

an indirect process of inestimable value to the agriculture of the world; 3000 horsepower is being turned to this industry by Niagara power here in Canada.

This may be as a good a place as any to speak of the Birkland-Eyde and of the Badesche Analin and Soda Fabrik processes for oxidizing the nitrogen of the air direct and converting it into nitric acid and other nitrogen products. Both of these are established industries in Europe to-day, and must soon call for not only large but cheap power in America.

As reported by Sir Oliver Lodge, it is found that vegetation is greatly stimulated by electricity at Britton in England, as shown by the experiments of Newman and Bomford of Gloucester and Salford respectively, and that an increase of from 30 to 40 per cent in the yield of wheat in the treated over the untreated grain was obtained, and that the quality was better and commanded $7\frac{1}{2}$ per cent higher price. These results were obtained by stringing wires through the field of about eleven acres and energizing them with a current of 100,000 volts, its leakage to the earth doing the work.

A friend of mine, keeping a hotel at Franklin, N. H., some years since had a rubber tree in the office of the hotel which was in a large window having good light in the day time and having electric illumination every night till nearly midnight. It made a most extraordinary growth in a few weeks. Electrolizing the soil has also been found to stimulate vegetation and augment its growth.

The chemistry of new products, as well as the "Chemistry of common things" has received perhaps its greatest advance from the work of Dr. E. G. Acheson, who first developed carborundum from a mixture of coke and sand in the electric furnace, the whole rendered all the more remarkable from the extreme simplicity of the furnace itself, being in reality a rectangular assemblage of bricks without mortar, such as a small boy might arrange. The work of Dr. Acheson is a beautiful illustration of the simplification of chemical processes made possible by the agency of cheap and abundant electricity, under the manipulation of a master hand. Carborundum has largely taken the place of expensive emery and made a place for itself as well, so that large furnaces and power are used in this industry by the Carborundum Co. at Niagara Falls.

Following quickly this development was his production of graphite from coal and its substitution for the natural graphite for many uses, but this artificial product has also made a place for itself such as was never thought of for the natural graphite. Moreover the culm piles are a cheap and excellent source of carbon for this manufacture. Electric terminals made from graphatized carbon are stronger and better electrical conductors and more resistant to chemical agents and more enduring than the carbon electrodes they so often displace. They may also be machined and shaped at will.

The further masterly work of Acheson is shown in making the flocculated graphite and then the deflocculated, which produces a solution of graphite which is utilized in his lubricants, Oildag, Aquadag and Gredag, some of the most remarkable lubricants in use to-day.

Mr. J. A. Tone has made practical the production of silicon and is finding uses and a market for the product.

Electrogalvanizing is largely practiced instead of dipping in molten zinc, giving a sufficient and cheaper coating of zinc, beautiful and suitable for many purposes.

Electroplating is one of the oldest applications of electricity to chemistry and needs no remark here beyond the statement that the process is constantly being extended, and used more and more as a means of recovering metals from their ores. This is especially true of copper, which is now and has for some years been obtained in sheets of any desired thickness after having first been deposited on large cylinders from which it is cut, making sheets several feet square of great purity and ready to be cut into any desired shapes. The electric smelting of lead, zinc, antimony and a number of other metals is a certainty of the very near future.

Electrically fused quartz has in recent years placed in the hands of the chemist apparatus adapted to stand exceedingly high temperatures and susceptible to such sudden changes of temperature as to greatly extend the work of the laboratory. It must ultimately take an important place in industrial chemistry. The manufacture of bi-sulphide of carbon, phosphorus and the distillation of turpentine in the electric furnace or still, point to the early elimination of retorts for all manufacturing processes. When one considers the size limitations of retorts, the expensive

materials of which in many cases they are made, their frailty in the case of glass, and their susceptibility to corrosion and multitudes of other defects and inconveniences, a whole field is opened for the application of electrical processes for chemical manufacture, distillations and sublimations that have never yet been touched. Moreover, some of these future applications of electricity will clean up some of the most disagreeable of all our chemical processes.

Gerod electric steel furnaces are now in use by eleven large establishments, while of the Herouldt furnaces there are in operation nineteen in Europe, four in the United States and one in Mexico. Some of the furnaces are of fifteen tons' capacity. In the electric refining of iron and steel the quality of the metal produced is so much better than that obtained from former methods as to point to its rapid advance and adoption now that the process has fairly entered the commercial and manufacturing stage. Indeed, the qualities of crucible steel can be given to inferior materials and it is probable that from like materials a steel superior to the present crucible steel will soon be obtained, the limitations of the crucible removed, and crucible steel for all practical purposes made on a scale never to be attained by any crucible process. Thus does electricity not only enable us to make a better product, but in such quantity at one operation as to greatly cheapen the production. At Trolihatten, Sweden, a 2500 H.P. shaft electric furnace for smelting iron ore and the manufacture of pig iron is now being erected, having been justified by the working of a smaller furnace.

For the accomplishment of the work of the large chemical industries that are here, and are coming, there is nothing more important than the true conservation of our water power resources. Niagara Falls is such an important seat of power on account of the natural conservation of water in the Great Lakes. But water can be artificially stored in many places where extensive water power possibilites are now allowed to go to waste. We should stimulate public sentiment against the absurd policy of wiring electricity, for example, from Niagara Falls across the State of New York as far as Utica, passing streams which if properly conserved by storage reservoirs in their headwaters would supply in a regular and dependable way an abundance of power without such diversion.

No one has keener appreciation of the omissions of this paper than the author, but he hopes this brief presentation may serve to stimulate our zeal to have a large part in the new and cleaner industrial chemistry that awaits our best engineering ability.

Discussion

President McKenna:

The subject of carriage of power from this point to points where it can be economically used, makes me think that perhaps the solution of the problem would be, that this power might continue to be used for an indefinite period as far as Utica, while power from the headwaters of the rivers and streams of the state in the Adirondacks should be carried away from these cities, such as Utica, to our large cities—to the great metropolis, because it is hoped that the smelting of iron ore by direct processes will yet find their home at that point. The plentifulness of scrap, the large amount of skilled labor to be had, and the immediate market for the product, all point to the possibilities of the success of the electric furnace at tide-water, in New York City, if only we can harness the energy in the headwaters and upper sources of the rivers, and carry that power to New York City. I am not sure that it would be an economical contradiction then to carry the Niagara power as far as Utica, and harness the power at that point, and carry it to tide-water. These are not dreams, for the New York State authorities are actively engaged in conservation, and are following up, as far as possible without actual expenditure for construction, the project for the utilization of these powers.

I would like to hear a discussion of Mr. Taylor's paper.

Mr. Camp:

We have a furnace at Homestead, but it is only in the experimental stage. They are doing more work at South Chicago and Worcester than in our neighborhood, and I regret to say that we have not learned very much about it. We are running the furnace, and making good steel, and there is no question about the betterment of the product. In fact, I know that steel made in the electric furnace is being sold and used in place of crucible steel without any diminution in price. They will have to come in time. The Crucible Steel Co. of America are going to adopt the process, and have made contracts for furnaces, but

have not done any work as yet. The line of work at the South Chicago plant has been in the betterment of rail steel. They use Bessemers for the heating, and pour the molten steel into the electric furnace, giving it about an hour's treatment and removing the gases. It is possible to get any kind of an atmosphere, and to use any kind of slag—acid or basic. The steel runs out like molasses without any scintillation or effervescence. The benefits are very pronounced.

PRESIDENT MCKENNA:

Have any plants for the economic production of steel been started on steam-raised power?

MR. CAMP:

No. Nearly all plants of the corporation are putting in gas engines operated by blast furnace gas. We have about 5000 H.P. running now on blast furnace gas, and I think it is only a question of time when the modern steel plant, on account of the scarcity of the finer grades of coal, Bessemer ore and low phosphorus ore, will substitute one of the two processes, Bessemer and electric, or the open hearth and electric. The advantage of the Bessemer and electric lies in the economy of ground. There is a big future for this process in all steel plants, and we can see the revolution coming now.

SECRETARY OLSEN:

At South Chicago do you get your current from the gas engines, and find that economical?

MR. CAMP:

It has been figured out by engineers of the Carnegie Co. that with coal at $1.00 a ton there is not much economy in gas engines at the present time. It is just as cheap to generate the steam. That is on account of the enormous first cost of gas engines. There is an enormous expenditure necessary for purifying the blast furnace gas, then the cost of the gas engines, and then of the large electric generators, must be added. There are thus three installations against one in the other case.

PRESIDENT MCKENNA:

At the Crucible Steel Co.'s plant they have no blast furnace gas?

MR. CAMP:

That is where they make the raw product. It is melted in pots to make the crucible steel. In the new style furnaces they start with pig iron and steel scrap. If you can add the charge molten, and use the electric furnace to purify the metal, it is very economical. The large consumption of power comes in melting the charge. That is where they should have the blast furnace to give them cheap power.

DR. LIPPS:

At Ginn in Germany they make use of the water power of the Rhine. In the small plant they have a small producer gas furnace 10 ft. high, and $2\frac{1}{2}$ ft. in diameter in a room about 20 by 20, connected with a gas engine and the gas engine runs a dynamo. This gives all the power they need in the plant. Yet they have cheap water power, from which they get the current for the city.

MR. R. E. FOWLER (National Electrolytic Co.):

I would like to make one comment with regard to the use of electric power. It has been stated that the use of electric power would do away with the use of coal to a certain extent. But it is not an unmitigated blessing. Every one of the industries employs a large amount of coal as well. The advantage has been only to shorten chemical operations. Whereas formerly a dozen operations were necessary, the use of electric energy gives the same result in one. In all the institutions a large amount of coal is used as well. The amount of smoke from them during the last eight or ten years has been tremendous, and living in certain parts of the city here has been made very objectionable. While it has been of decided advantage in cheapening output, it has not done away with the smoke nuisance, nor has it done away with other objectionable nuisances in the way of dust and gaseous products.

NOTES ON THE CORROSION OF IRON AND STEEL AND ITS PREVENTION

By G. W. THOMPSON

Read at the Niagara Falls Meeting, June 22, 1910

It is not my intention in this paper to discuss the various theories which have been advanced regarding the corrosion of iron and steel or even to discuss in detail the corroding operation. This subject has received very general consideration; and while there are differences as to matters of theory, there is fair agreement as to facts. It will not be possible for us to divorce the description of facts entirely from the terms which theory has given us, and we shall not hesitate to use these terms when occasion warrants it, simply asking that, if the reader does not accept the theory which is responsible for the terms, he shall translate these terms into such other terms as more nearly agree with his theoretical conceptions.

By the corrosion of iron and steel, we refer to the oxidation which takes place at ordinary temperatures, with the formation of rust. Rust approximates the following formula:

$$Fe_2O_3.3H_2O,$$

although all rust does not exactly conform to this formula.

A sample of rust, obtained by exposing a thoroughly cleaned piece of steel, that is, a steel which had been pickled to remove the scale, etc., analyzed as follows:

	Per Cent.
Hygroscopic moisture	8.83
Combined water (including CO_2 0.17%)	21.45
Ferric oxide (equivalent to iron 48.28%)	68.97
Silica	.26
	99.51

The ratio between the combined water and the ferric oxide corresponds, approximately, to the chemical formula given.

It is to be noted, however, that in addition to what is known as the combined water, it contains a relatively large amount of hygroscopic water. The nearly nine per cent of hygroscopic water shown in the above analysis corresponds to nearly thirty per cent of water by volume.

A very importnat consideration in connection with the formation of rust is, the specific gravity of iron is about 8.70, and the specific gravity of rust is about 3.70. If the iron and the rust are strictly pure and of theoretical composition, the iron shows an increase in volume in conversion to rust equal to 336 per cent; that is, 100 parts of iron become 436 parts of rust by volume.

Often rust has associated with it the mill-scale which is formed in the process of rolling or other hot treatment—this scale consisting of slag and oxides of iron, more or less similar to magnetic oxide.

If we consider a rusting surface together with its atmospheric surroundings as a material system, corrosion may be due to forces operating within that system or to forces coming from without the system, such as stray electric currents. Corrosion of the former kind should be considered as primary corrosion, and the latter kind secondary corrosion. Primary corrosion may also be considered as autogenous. In the terms of the electrolytic theory of corrosion, primary corrosion is due to primary or autogenous electrolysis, while secondary corrosion is due to secondary electrolysis.

The prime material factors in corrosion are air and moisture, and the action of air and moisture is accelerated or retarded by other factors.

The tendency of iron to corrode has been considered to vary with the composition of the metal, but, apparently, facts do not warrant this conclusion to an extent that would justify general dependence on a purer and more expensive metal as against a more impure and cheaper metal. Practical experience may justify such a dependence in isolated cases, but not as a general rule.

Nevertheless, corrosion, which usually takes place in the form of pitting, is unquestionably due to the greater tendency of the pitting parts to corrode than the adjacent parts. Such corrosion

is said to be due to a higher electrolytic solution pressure as compared with the adjacent parts, and the corroding area is said to be electro-positive to the surrounding area. This, of course, refers to primary corrosion, to which most of our remarks will be directed.

The corroding operation is supposed to be, first, a solution of the iron in the water and, second, the oxidation of the dissolved iron by the air, with the formation of ferric hydrate or rust. This solution would not take place without the water being present, nor would the oxidation take place in the absence of air. The solution of the iron is accelerated by the presence of carbonic or other acids and neutral salts, also by the presence of substances which are electro-negative to iron. The corrosion is furthermore accelerated by the presence of substances or conditions which increase the amount of moisture on the surface, as by hygroscopic substances, such as rust itself or a moist atmosphere.

The oxidation of the iron is accelerated by the presence of oxidizing or depolarizing substances. Ferric hydrate can give up a portion of oxygen to iron, being reduced to ferrous hydrate, or it can act as a depolarizing agent by oxidizing the hydrogen supposed to be liberated by the solution of the iron in the water.

The acceleration of the corrosion of iron by the presence of acids is supposed to be due to an increased concentration of the hydrogen ions. Whether this is so or not, it is found that the presence of substances which are supposed to decrease the concentration of the hydrogen ions, that is, increase the concentration of hydroxyl ions, tends to retard corrosion. Iron does not rust in solutions of alkali of sufficient concentration.

Let us summarize these causes of corrosion and, in general, the methods which can be suggested for its avoidance.

1. Corrosion is superficial; therefore,
   (*a*) the area of the surface is a positive factor in corrosion, and
   (*b*) the prevention of corrosion is most naturally accomplished by superficial protective coatings.

2. Corrosion is an oxidizing action; therefore, oxygen and substances that liberate oxygen under ordinary conditions should be kept away from the surface subject to corrosion as far as is practicable.

3. Corrosion starts with the solution of the iron in water; therefore, moisture and moisture-absorbing or hygroscopic substances

should be kept away from iron and steel; and, furthermore, as the tendency of iron to go into solution is variable, the surface should be made as passive in this respect as is possible.

4. Corrosion is accelerated by the presence of acids—the most prevalent acid being carbonic acid; therefore, acids, especially carbonic acid, should be kept away from the surface; and, furthermore, as alkaline solutions of sufficient concentration retard corrosion, their presence should be favored, unless good reasons exist to the contrary.

5. Corrosion is accelerated by the presence, on the surface of the metal, of substances, whether a part of the iron or not, that have lower solution pressures than the iron; therefore, such substances should be eliminated.

6. Corrosion is assisted by the presence of depolarizing substances which, in general, are substances that under ordinary conditions are capable of reduction. Especially is this so when the depolarizing substance is one that is capable of regeneration by oxidation. Rust itself is a depolarizing agent of this character, and, therefore, rust and similar depolarizing substances should be kept away from the surface.

In this paper, we are using theory only so far as it will guide us to practical results. We have endeavored to outline all the known causes of corrosion and its prevention, and we will now study these causes and the methods available for their prevention a little more in detail.

Corrosion is superficial. The constructing engineer should keep this constantly in mind and should design structures with as little exposed surface as possible. This he can do, of course, only in so far as such design is consistent with strength, flexibility and appearance, giving, where other things are equal, a preference to the design that has the smallest amount of superficial area. We believe that much structural steel work of the lattice type, if considered from this standpoint, would be condemned, and that plates would be used in place of lattice work to greater advantage. Rounded or flat surfaces should be given the preference over angular surfaces, whether in relief or in recess. A square bar has over twelve per cent more surface than a round bar of the same sectional area. Furthermore, a rounded section is less subject to abrasion than an angular section. It is the edges of painted structures that wear off the soonest and which corrode the most

quickly. So, too, the smoother a surface is, the less is its superficial area. A rough surface is doubly bad, because, in addition to its relatively high area, the indentations form moisture-holding pockets.

Effective protective coatings are of two general types—excluders and inhibitors—although it is probable that no protective coating is entirely one or the other. Tin or tin plate is principally an excluder, while zinc, in the case of galvanized iron, is principally an inhibitor. The best plan would appear to be to have the interior coating an inhibitive coating, and the exterior an excluding coating. Thus, if it were practicable to place a tin coating on galvanized iron, a combination of excluder and inhibitor would be obtained.

In the painting of iron and steel, several distinct subjects present themselves for consideration:

1. Cleaning the metal.
2. Design of paint coatings.
3. Application of paint.
4. Repainting.

Various methods have been proposed for the cleaning of iron and steel. These may be considered under the following headings:

1. Shop-cleaning with wire brushes.
2. Pickling.
3. The sand-blast.
4. Cleaning with wire brushes on or after erection.
5. Cleaning by exposure to remove mill-scale, with the subsequent use of wire brushes, etc.

There can be no question that iron and steel should be as thoroughly cleaned at the shop as possible. We have a feeling that more attention, at some time in the future, will be given to this phase of the subject, and that the producers of steel will work towards the production of a polished surface.

There is no better method of cleaning small objects than by pickling. The following procedure has been found satisfactory:

Dip the articles, if at all greasy, in a hot ten-per-cent caustic soda solution; then in hot water; then for, say, ten minutes in hot ten-per-cent sulphuric acid; then in hot water; then in hot ten-per-cent carbonate of soda (soda ash) solution; rinse well in hot water, and pack in slaked lime until time for painting has come. Remove from the lime; wash well with water; brush

clean and dry rapidly. The articles when dry will be ready to paint.

The use of the sand-blast is seldom applicable. It is effective but costly. It is probable, however, that the sand-blast removes considerable iron as well as objectionable substances.

The use of the wire brush and scraper, with the hammer where necessary, is the most practical way of cleaning, so far as the mechanical phase of the subject is considered. Mill-scale, however, is not readily removed by wires or scrapers. There is some difference of opinion as to the desirability of removing all the mill-scale. Our own experience is that mill-scale, unless completely removed, is apt to become loosened and to come off later on, carrying the paint with it in sheets. It is for this reason that the fifth method of cleaning has been suggested.

On exposing iron and steel to the weather, a certain amount of oxidation takes place, which is said to loosen the mill-scale so that it can be removed quite readily by wire brushes and scrapers. This system has been followed very generally in some sections of the country and has much to commend it, although, on the other hand, there are good reasons to be advanced against it. One reason for it is that, if the mill-scale should become loosened after painting, insidious corrosion could take place which would not be discovered for a long time. On the other hand, to expose the iron and steel to the weather involves the corrosion of good metal as well as the removal of the scale and makes the removal of all the rust so formed exceedingly difficult.

The proper cleaning and painting of large structures is often difficult on account of design. We would urge that painting is an important matter to consider by designing engineers and that such painting and the incident cleaning of the steel be contemplated in the design of the structure and made as easy as possible.

In the selection or designing of paint for iron and steel we believe that there are certain principles which should guide us. Protective coatings, as we have already indicated, may be considered as of two classes—inhibitors and excluders. For practical purposes, however, this division is not entirely satisfactory. It would appear better to consider paints according to the prime purposes for which they are applied. Classifying paints from this standpoint, they should be considered as protective or finishing paints. Protective paints are applied primarily for the protec-

tion of the iron or steel, while finishing paints are more for decorative purposes.

Considering protective paints, the principles which should guide us in their design or selection are as follows:

It is desirable that each coat of paint have a distinct color so that the painting can be inspected and imperfections in the workmanship observed. For this reason, it is not wise to select paints for all coats of exactly the same composition. By far the greater part of the failure in the protection of iron and steel by the application of paint is due to poor workmanship, and from this standpoint alone the selection of the color of each paint coating is an important matter. The use of linseed oil as a priming coat is to be condemned, because it cannot be told whether good workmanship is being done or not. This applies also to all paints similar in color to the metal painted. Very often a paint is condemned as being difficult to apply when in reality the difficulty lies solely in the fact that imperfections in workmanship are readily observable. In this sense, it is difficult to apply any paint that is distinct in color from the surface to which it is applied. The difficulty of application from this standpoint is a merit rather than a defect.

We have condemned the use of linseed oil as a priming coat for iron and steel for the reason that it is impossible to tell whether the application has been well made or not. But, more important than this, a linseed oil priming coat should be condemned for the reason that all undercoats of paint should be as hard as possible, which is not obtained when a linseed oil priming coat is used. Whatever rust-preventing power subsequent paints may have tends to be nullified by being separated from the iron and steel by a linseed oil film. A hard protective coating gives the best possible foundation for a subsequent paint.

As far as possible, the pigments contained in protective coatings should be inhibitors of corrosion and non-conductors of electricity. The paint should contain no water-soluble constituents, especially such as are electrolytes. Paints which contain pigments containing electrolytes favor both primary and secondary electrolysis.

Protective coatings should be as impermeable as possible. To accomplish this end, each coat should have a reasonable thickness. If the paint is brushed out too thinly, one or more addi-

tional coats must be applied to give proper thickness of coating. The impermeability of paint is greater, the greater the amount of the pigment and the finer the pigment is; so that the rule may be laid down—the higher the percentage of the pigment and the finer the pigment, the better will be the protective coating. Of course, you cannot increase the percentage of pigment beyond what will give a good working paint, and you cannot increase the fineness of the pigment beyond what will permit you to have a sufficient amount of pigment present.

From these considerations it would appear that the principles which should guide us in the selection or design of a good protective paint for iron and steel are:

1. Each coat of paint should be distinctive in color from that of the iron and steel painted and from the preceding coat.

2. It should form a hard adherent foundation for finishing paints.

3. Its pigment constituents should not accelerate corrosion.

4. The paint should insulate the iron and steel.

5. The paint should contain no compounds appreciably water-soluble.

6. The paint should be as impermeable as possible.

In considering these principles, we should bear in mind, however, that no one of them is a determining factor; that all should be considered together, each with its respective value. No protective coating should be judged by one quality alone.

Little can be said regarding finishing coats, as color is most often the determining factor. Black paints are much desired for finishing coats and they are excellent for this purpose, as they are usually fairly permanent and impermeable. Asphaltum should not be used in protective coatings, except to the extent that it can be assimilated in varnish so that it becomes insoluble in further coats of linseed oil or other paint vehicles. The dark greens and olives are exceedingly serviceable as finishing paints. If a good protective paint is used, almost any reasonably good finishing paint can be applied.

Good workmanship in the application of paints to iron and steel is more important than the actual selection of the paint. Labor is the principal item of cost. Many a good paint has been applied by incompetent workmen, so that, in effect, both labor and material have been thrown away.

That portion of the Havre de Grace bridge of the Pennsylvania Railroad, painted under the auspices of Committee E of the American Society for Testing Materials, is in excellent condition after three and a half years' exposure. There were nineteen different paints applied and they were applied so well that practically all of them appear to be doing good work.

The proper inspection of a painting job is too often neglected. It is our opinion that painting inspectors should be more often employed than they are.

Corrosion is an oxidizing action, but, unfortunately, we know of no method of keeping oxygen from the surface of iron or steel except by means of protective coatings; and it is doubtful whether in this respect they are in any degree effective. But, as iron will not rust except in the presence of moisture, it would seem unnecessary to take any steps to exclude oxygen from the surface of the iron, while decided steps should be taken to keep out moisture. On the other hand, substances that liberate oxygen under ordinary conditions and become in effect depolarizing agents, should be kept away from the surface of iron and steel. This will, however, be spoken of further on.

Moisture is, however, something that should be kept away as far as possible from the surface of iron and steel. This can be done to some extent by protective coatings; and in the selection of protective coatings, their moisture-absorbing or hygroscopic qualities should be considered. Unfortunately, very little or no work has been done on this subject. It is probable that a pigment which is hygroscopic before mixing with oil will remain hygroscopic to some degree after mixing with oil. It is probable, however, that some pigments, by their action upon the linseed oil, may increase the hygroscopic qualities of the oil itself. The principal vehicle used in protective paints is linseed oil. It is a glyceride, and under some circumstances it becomes decomposed with the liberation of glycerine.

It would seem possible that glycerine, being a hygroscopic substance, would affect, to the degree that it is liberated, the moisture-absorbing quality of a protective coating. Much study should be given this phase of the subject.

The solution of iron and steel is the first step in corrosion, and has received considerable study in connection with attempts to make iron and steel passive in this respect. The most interest-

ing work along this line has been done by Messrs. Cushman and Walker in the use of chromates. It is found that a clean steel wire, dipped for a few minutes in a solution containing chromic acid, does not rust so readily as before such treatment, and it will not precipitate copper from copper sulphate solution. The theory of this is variously expressed; and the reason why chromic acid acts in this way is all a matter of conjecture; the practical fact remains that chromic acid does make iron passive. It would appear that its electrolytic solution pressure becomes reduced nearly to zero, and that the solution of iron in water is a negligible quantity. It is impracticable to treat iron with chromic acid to make it passive, as this passive quality is evanescent. The best that has been suggested so far has been to introduce or use in protective coatings chromates which are sufficiently soluble to maintain this passive state. Many suggestions have been made along this line, none of which, however, has become of commercial importance. The field, however, is promising, and it is to be hoped that something in the near future will develop.

In locations where the tendency is for the moisture contents of the air to be high, it would seem proper that steps should be taken to reduce that moisture to within reasonable limits. Everyone is familiar with the sensation indicating high moisture contents in the air of subways. It is uncomfortable to the traveler and not favorable to the protection of the steel columns and girders. This moisture can be reduced by systematic cooling devices and by the use of lime etc., and should be done to a point where the cost would not become prohibitive.

In the design of iron and steel structures, proper thought should be given to the draining of condensed moisture or rain. The lower part of lattice columns should be filled with concrete with a crown to carry off the water, and every other method that can be suggested should be followed as far as practicable to prevent water from remaining in pockets.

The acceleration of corrosion by the presence of acids and salts should be avoided by every practical means. In subways and other places where carbonic or other acid may be excessive in the atmosphere, lime should be freely used. It would seem possible to devise a system whereby lime thus used could be regenerated periodically. Where liquid acids are of necessity present, an attempt should be made to neutralize them by the use of alkali. In the

case of refrigerator cars, which are thought to be the cause of much corrosion on steel bridges, special precautions should be taken to discharge the drip out of the range of the bridge or by some other means to prevent this dripping. The use of alkali and alkaline earths to prevent corrosion is effective as far as it goes. The embedding of steel in concrete is along this line. The practice of putting lime around the footings of steel columns is a good one. Lime may not exist in concrete in the free state, and yet there seems good reason to believe that, as far as results are concerned, concrete acts in the prevention of the corrosion of iron and steel just as caustic lime does. The aging of concrete and the aging of lime, however, result in the final neutralization of the caustic constituents by the absorption of carbonic acid, and carbonate of lime is not so effective in retarding corrosion as caustic lime is.

The acceleration of corrosion by the presence on the surface of iron and steel of substances which develop primary electrolysis, through their having a lower electrolytic solution pressure than the iron itself, should be avoided as far as practicable, but this is not saying much. We do not know of any practical method of securing such homogeneity as will not permit of local polarity being present. Unequal strains, inequalities in composition—all tend to develop local corrosion. The best that can be done here is to use protective coatings which keep out the other agents of corrosion.

Acceleration of corrosion by the presence of depolarizing substances can be avoided principally in the removal of rust, before painting, and repainting wherever rust spots appear. Rust itself is the principal depolarizing agent in corrosion. Its alternate reduction and oxidation and its moisture-holding properties make it very desirable that rust, as fast as formed, should be removed and the rusted surface painted. It is not always practicable to remove rust completely when once formed, but this removal should be as complete as possible.

Corrosion of iron and steel, as caused or accelerated by outside currents producing secondary electrolysis, is something that should be avoidable with comparative ease. The insulation of steel structures at their foundations, the proper insulation at joints, and the proper painting should reduce this damage to a minimum. This cannot, of course, be said in regard to water and

other underground pipes. Here, the foe is insidious; and yet, careful measurements should be made from time to time and stray currents avoided. A phase of secondary electrolysis to which but little attention has been given is that which results from induced currents and such currents as may be generated through daily variations of terrestrial electric currents. As far as these are concerned, it would appear that the only method available for the prevention of corrosion resulting therefrom is by the use of protective coatings.

Discussion

Maximillian Toch:

The paper by Mr. Thompson and the notes on the Corrosion of Iron and Steel and its Prevention, contains much that is of interest. It has always been my belief that complex specifications for the cleaning and painting of steel are useless. The man behind the brush, and the man above the man behind the brush, appear to me to take particular pains in trying to break or disobey any rules that the careful manufacturer would prescribe, and I therefore conclude that the best kind of paint to use for the protection of steel is a paint which almost any laborer can apply, and which will combine with incipient rust.

The latter condition is one which is of great importance, for it is all very well to write out particular orders and commands that all rust shall be removed. In the twenty-six years of my personal contact with the steel producer, I have never found a case where paint was applied to perfectly clean steel except in the laboratory.

I agree with Mr. Thompson in many of the things which he says. Each successive coat of paint should be of a different color than the preceding one. The harder the priming coat the better the finishing coat and so on, but I do not quite agree to the principle, that steel should never arrive on the field oiled. I assume that Mr. Thompson speaks entirely of raw linseed oil when he talks of oil, and in that I heartily concur, but a hard drying reduced boiled linseed oil is by far preferable to anything that I know, for the reason that it is the lesser of two evils.

Of course there are some large bridge companies and steel erectors who are conscientious, and employ good workmen. My

experience has been that the majority of the smaller steel companies still worship Hermes as a god or a patron saint.

Lime does exist in concrete in the free state, but I have never believed in the school book text that caustic lime in building concrete is always converted into carbonate by the action of the air; in fact, I know that this is not the case. Even in my examination* of the Gillender building, I found the mortar after fifteen years was still alkaline on the interior, and that the lime was in a $Ca(HO)_2$ condition with but slight traces of CO_2 on the shell.

Lime may carbonate on the exterior, as a matter of fact it does, but on the interior it cannot carbonate for obvious physical reasons, and it either remains in its original condition or else it forms a very basic silicate. As I have pointed out on many occasions, cement mortar is a totally different thing in its physical action towards steel than cement concrete.

Mr. Thompson's remarks on the inhibiting quality of certain chromates, is very interesting, indeed, and bears out my personal experience in the matter. It does, however, demonstrate one thing conclusively, that a laboratory experiment is incomparable with field experience. In the laboratory chromic acid and the chromates showed up wonderfully well. In the field they have not demonstrated their utility at all. I am not prepared to say that they are not good, nor am I prepared to say they are good, as just now I am inclined to agree with Mr. Thompson they may be either one or the other. A true inhibitor is a paint that can " bleed " small quantities of lime, for we are all fairly well agreed; that lime is as good an inhibitor as we have.

Mr. Thompson is to be complimented upon the care and precision with which he has covered this subject, and whenever he gets up to say something he has a message to deliver, and I am very glad of the opportunity that has been given me to discuss this paper.

ALLERTON S. CUSHMAN:

Mr. Thompson gives his usual clear explanation of the underlying principles which govern the corrosion of iron. Although disclaiming especial adherence to any particular theory, it is apparent that Mr. Thompson argues from the standpoint of the electrolytic, or, as he prefers to term it, the autogenetic-electrolytic

* See page 54, *Engineering News*, July 14, 1910.

theory. Indeed Mr. Thompson's summing up of the subject constitutes another plea for the wide and useful application of this theory to practical problems. As an advocate of the electrolytic explanation of corrosion which he has done much to develop, the writer can only reiterate that it is to him no longer a *theory* but the only explanation in accord with all the facts. The solution-tension, passivity, and nodal effect, as shown by the *ferroxyl* indicator, are facts which lead directly to the design of inhibitive protective coatings. Owing to improper design it is possible and also probable that many inhibitive coatings will fail in test and in service, and the results will continue to be sneered at by ultra-conservatives as well as by those who are interested in advocating the use of stimulative materials for so-called protective coatings. There would be nothing new in such a situation, the steam engine, the Atlantic cable and the aeroplane were all pronounced impossible in advance by very eminent persons. In the writer's opinion properly designed inhibitive coatings will ultimately be called for in every specification, and it is now only a question of learning how to combine materials so as to achieve the maximum inhibitive effect with the minimum bad effect on the desirable qualities of the vehicle.

With one statement of Mr. Thompson the writer cannot agree. He states that good workmanship in the application of paint to iron and steel is more important than the actual selection of the paint. That good workmanship is highly desirable goes without saying but a cheap "doped" paint in the hands of a master-workman would inevitably fail. Whether it would fail before a properly designed paint in the hands of a careless inefficient painter, no one can say, but Mr. Thompson's dogmatic statement seems to minimize the importance of the proper selection of materials and throws most of the blame for the too often recurrent failures on the man with the brush. As this statement of Mr. Thompson is one that is often heard the writer takes this opportunity of questioning it.

Mr. G. W. Thompson:

To the comments on my paper it is hardly necessary for me to make any reply, as they are not materially at issue with anything that I have said.

My paper was written from the engineering standpoint with the idea of covering the ground outlined as fully as possible, so

that the constructing engineer could have all of the points to be considered before him, subjecting his specifications to a categorical examination. I have endeavored to consider the art as it exists at the present time, advising as far as I could, certain methods of procedure and certain things as being of greater importance for consideration. For instance, I emphasized the importance of application. My position on this point is incontestable in the present state of the art. I know of no paint on the market that can be applied and give satisfactory results without proper attention to the application and without that application being made by relatively skilled labor. When such a paint becomes a commercial article and is recognized as such, then the relative importance of application becomes changed.

The constructing engineer needs certain rules to guide him and I have attempted to suggest some of these rules. Ten years from now some of my suggestions may become obsolete, although the history of the art of protecting iron and steel does not indicate that this will be the case. All new ideas have to fight their way against established ideas, and in this irrepressible conflict these new ideas become established or the old ideas become more firmly established. This is what makes progress.

PROTAL:

A NEW PRODUCT FOR USE IN THE ARTS

By F. G. WEICHMANN

Read at the Niagara Falls Meeting, June 22, 1910

President CHARLES F. MCKENNA:

Some two or so years ago, one of our charter members confided to the officers that he had made the discovery of a new substance, and he was begged to make it known. The time was not then ripe, however, as his experiments were not completed, but he made a promise that he would not present it to the world except through the Institute, and although importuned by other societies and journalistic mediums to make it public, he has kept his promise to us. I have the pleasure of introducing to you Dr. F. G. Wiechmann, who will tell us about a new body for use in the arts.

Dr. WIECHMANN:

On account of the present great activity in the rubber industry, and the enormously increased demand for rubber, the presentation of a new substance which possesses a number of valuable qualities and which can be used in many of the arts and industries where rubber and similar materials are now employed, would seem to be of timely interest.

When, in 1844, Goodyear announced to the world the discovery made in 1839, that he had succeeded, by the use of sulphur and the influence of heat, in producing plastic, semiplastic and hard bodies of rubber suitable for use in the arts, a new industry was born. Prior to that time there were few uses for rubber. Since that time the industry has grown until to-day it has become one of the most important of industries.

Statistics show that the actual capital invested in the rubber trade in North America is approximately $150,000,000 at the present time, and the industry employs not less than 100,000 men. The rubber industry has been the parent of other industries, among

which may be mentioned those of the manufacture of bicycles and automobiles. The use to which rubber compounds may be put in the arts has increased to such an extent that to-day the production of rubber does not meet the demand.

Within the last year the trade has seen the price of rubber greatly advanced. The average price for Upriver, Fine, Para rubber was, in:

1907	$1.09¼
1908	0.93¼
1909	1.59¾

The range of prices of this grade of rubber was, in:

1908 low	$0.70	in March
1908 high	1.30	in November
1909 low	1.20	in January
1909 high	2.15	in September

In 1910 the figures quoted were:

January 1st	$1.64
February 1st	1.80
March 1st	2.00
April 1st	2.53
May 1st	2.77

For these figures I am indebted to the courtesy of Mr. Hawthorne Hill, Associate Editor of the *India Rubber World*.

This advance in price, as in other industries, has made impossible the use of rubber for purposes which were possible at from 80 cents to $1.00 a pound, or, in other words, commerically impracticable.

The continued and steady advance in the price of rubber has naturally directed the attention of technical chemists to the production of substitutes for it, but up to the present time, it would seem that no satisfactory substitute for rubber has been discovered. It is true that valuable substances have been produced, such for instance as celluloid, which have taken the place of rubber for certain uses, and that many other materials have been produced, for instance, shellac compounds, which have also been used in place of hard rubber for certain purposes, but, as before stated, it is believed that no substance or compound has been produced

which may be used in the same manner and for all of the purposes for which hard rubber has heretofore been employed.

The shellac compounds mentioned, as well as all other compounds having the same characteristics, have, in a measure, been found unsatisfactory, owing to the fact that their composition is based upon the use of a body of some kind and a binder. The only binder in this class of compounds which experience has proved to be of any particular value has always consisted of a resin, but the principal objection to resinous compounds is that they are oxidizable, that is to say, the resin is subject to an oxidizing process which destroys the value of the binder. In other words, the artificial resinous substitutes for hard rubber exaggerate the one great objection to the use of hard rubber in the arts, for everyone familiar with the rubber industry or the uses of rubber is aware of the fact that if hard rubber is exposed to the action of the atmosphere, or to the action of a body which will set free oxygen, deterioration of the rubber will take place more or less rapidly. The only situation in which hard rubber may be used without incurring such deterioration is where it is so placed that it is not exposed in any way to the action of oxygen.

One of the reasons why a satisfactory substitute for rubber has not been found before is possibly owing to cognizance not having been taken of the fact that certain products of nature may be chemically acted upon to convert them into bodies which may be treated as is the case with rubber, and which, when treated, possess within themselves qualities, such, for instance, as strength, resiliency, non-oxidizability, which render them permanent compounds.

It now gives me great pleasure to announce that within the past three years I have succeeded in producing compounds, and to present to you samples of various modifications thereof, which possess many of the physical characteristics of rubber compounds, and which present the additional advantage that they are entirely free from the one principal objectionable feature of rubber, that is to say, they are not prone to oxidation.

Before entering into a description of this material, I would recall to your attention the splendid work, with which I suppose you are familiar, which has been carried on in this country and in Germany for the past ten years, relating to proteids and proteid compounds, at present the dark continent of chemistry.

The manufacture of the product which I here present to you

is based upon the employment of a natural proteid. It may cause some astonishment when I state that the combination of two protein bodies results in the production of a third body which is dissimilar in physical appearance or characteristics from either of the original proteids. The chemistry of proteids and the reaction of proteids upon proteids alone or in the presence of catalytic agents is difficult to express, either in language or in chemical symbols, and we therefore have to depend, to a certain extent, for the evidences of change and reaction upon the physical appearance and properties of the bodies produced by the bringing together of these substances.

The base of the material to which I direct your attention is, as before stated, a product of nature, and it occurs in nature in a great many different forms. I refer to vegetable-albumin. It will not be necessary for me to state in detail to you who are familiar with organic chemistry the numerous sources from which the vegetable-albumin may be derived.

But, while this vegetable-albumin can be derived from a great variety of sources, and while it is to be understood that under this generic term—vegetable-albumin—there are included many substances, such as vegetable ivory, vegetable caseins, the glutens, hemi-celluloses, reserve celluloses, horny albumins, etc., the form of vegetable-albumin which seems specially well adapted for the production of this new material is that occurring as the seed of certain palms, in which the vegetable-albumin plays the role of a reserve cellulose.

These seeds possess a hard, horny endosperm, and are found principally among the monocotyledons, especially in palms, liliaceæ, iridaceæ, and in plants of kindred species.

The seeds of some dicotyledons also contain vegetable-albumin—in the form of reserve celluloses, and it is generally found that, where such reserve celluloses predominate, there is little or no starch; these two substances seeming to be equally capable of sustaining the life of the germinating plant, the purpose which nature has destined them to serve.

One variety of palms, the *Phytelephas macrocarpa*, which grows especially in South America, produces hard, fine-grained seeds—the so-called Tagua nuts; these, for almost a century, have been used and valued for the manufacture of buttons and sundry other small objects produced by the turner's art.

The nuts are sent up here from South America and split up into discs. The button turner takes these discs, presses them against his very rapidly revolving knife, and all that remains is waste, in their industry, known as "ring waste." I have here one or two pieces of ring waste. The nuts at the present time cost about $170 to $175 a ton, and the waste of this material is approximately 70 per cent. Up to this time most of it has been burned under the boilers just to get rid of it. It has a low fuel value.

Similar seeds, or nuts, as they are commonly called, are furnished also by other varieties of palms, for instance, by the *Phytelephas microcarpa* and also by the cocoa palm, the seeds produced by the latter being generally termed Corozo nuts.

The vegetable-albumin which forms so large a percentage of this material is, by nature, intended to serve as food for the young plant embryo, before the same is able to procure and prepare its own nourishment.

Originally, this vegetable-albumin occurs as a liquid which is sometimes used as a drink by the natives of the country in which the palms grow, but, at a later period of its development, this material, after having passed through an intermediate, pulp-like condition, solidifies and turns into the hardest form of albumin known.

On germination of the young plant, however, it seems that enzymes or ferments appear, which again soften the hard mass and reduce it to a pabulum, fit and ready for assimilation by the new and growing plant.

Now, given an albuminous base of vegetable-albumin, it is possible, by adding to such a base an animal albumin together with any suitable solvent, to produce a compound which in physical appearance is different from either of the two bodies entering into the combination; to produce a compound which, so far as I am aware, cannot be separated by any known chemical process into its original elements; a body whose physical characteristics are different in that it has a tensile strength, an electrical resistance, and a solubility different from that of either of the bodies incorporated.

This material may be loaded with any of the materials commonly used in loading rubber, certainly more than eighty different substances having been used by myself for this purpose, and the addition of elastic bodies, resinous or non-resinous, including rubber,

this material may be employed to take the place of rubber in a large number of industries.

For this material the name PROTAL has been suggested because it indicates the source of the raw material, the first four letters of the word being derived from the word "protein," the last two from the word "albumin." In the further development of Protal, this name may, however, be said to have taken on a different, a wider significance, and may be regarded as indicative of the numerous—the Protean forms—in which this material is obtainable.

To summarize: Protal is the name of a new industrial plastic, the base of which is derived from the plant world, as the base of rubber is derived from the plant world, and which may be subjected to such treatment and processes as serve to convert it into a plastic semisolid or solid mass, having characteristics which permit such mass to be molded, cast, pressed, or otherwise formed into shapes, and possessed of such properties as to permit its use in a number of the arts and industries.

To produce the new plastic, the vegetable-albumin is treated by one or more substances, which, it is believed, convert it into a new substance, new not only in its physical, but in its chemical characteristics. By this expression, I would have it understood that the resulting material is neither vegetable-albumin, nor the material with which it is treated, but a *new* material from which the original components may not be recovered unchanged, at least not by any process known to me.

When first produced, Protal is perfectly plastic, but it soon acquires the hardness of stone; on rewarming, however, it resumes its plasticity sufficiently to permit of its being molded, under pressure, into any shape or form. In molding it takes sharp and clear impressions. The molding of articles from Protal can be done in either of the following ways:

1. The freshly made mix can be pressed directly without the application of heat into the desired form, and the article so fashioned subsequently dried. If this process is followed, proper allowance must be made, in devising the die or form used, for the shrinkage which occurs in drying.

2. The freshly made mix can be pressed, without the application of heat, into any convenient primary form—such as slabs, plates, discs, rods, etc.—and these dried. After being dried, the desired

articles can be pressed from such primary forms with the application of heat. If this process is followed, there need be no allowance made for shrinkage in devising the final die or mold to be used.

3. The freshly made mix is flaked or shredded and ground into a powder of any desired degree of fineness and this powder dried.

From such dry powder any desired article can, of course, be pressed or molded with the application of heat. The drying in this process and in those before mentioned is best conducted in a simple form of vacuum drier, or by the aid of a heated air current.

Protal is odorless, resilient; it can be cut, sawed, filed, polished, tapped and countersunk, like hard rubber and hard wood. It can be colored by dyes and all pigments can be incorporated with it. It is non-explosive, and when heated in a Bunsen flame it does not burn actively, but only chars and smolders.

In one series of experiments an electric current was passed through a German silver wire imbedded in Protal until the wire fused at $7\frac{1}{2}$ amperes. The Protal showed no signs whatever of burning. By the incorporation of certain chemicals, the heat-resisting qualities of Protal can be materially increased even beyond this point.

Protal in some of its forms is a good electric insulator. One hundred and eighty-four Protal compounds which were tested for their dielectric strength were found to range in their mean effective dielectric strength from a minimum of 512 volts per millimeter up to 10,276 volts per millimeter. Some of the values obtained were 6693, 7520, 8740 and 9567; the maximum value, as already stated, being 10,276 volts per millimeter.

In tensile strength, pure Protal compounds range from 1000 pounds to 2110 pounds per square inch. Of ten Protal compounds which were submitted to compression tests three, under a load of 100,000 pounds showed no compression whatever; two a compression of 8.3 per cent; one a compression of 10 per cent and four a compression of 16.7 per cent.

These tensile-strength and compression tests, all tests of record, were made in the laboratories of Dr. Charles F. McKenna, New York.

As before stated, it would exceed the limits of this paper to take up and discuss the properties and qualities of all of the many Protal compounds prepared.

Some compounds made proved to be of value for abrasive and

polishing wheels; some of these wheels were run at a speed of 4000 revolutions per minute, cutting iron, steel, brass, etc., with ease, and did not rupture when tapped while running.

Protal compounds with asbestos, shellac and the resins prove to be plastic and moldable and some of these compounds possess the remarkable quality of hardening to stone on immersion in water.

Compounds of Protal with linseed oil and various pigments incorporated therewith proved of a nature well adapted to the manufacture of linoleum.

The most interesting compounds of all, however, are perhaps those of Protal with rubber, rubber fluxes and a variety of so-called rubber substitutes. These compounds, according to the relative percentages of their ingredients, possess a wide range of hardness and flexibility; inspection of the samples here submitted will, however, probably tell the story better than any mere verbal description. As seen, this class of Protal compounds may be produced either soft, semisoft or hard, their quality in this respect being due to the proper choice of loading materials and the judicious application of varying degrees of heat and pressure.

Any and all colors and pigments may be incorporated with Protal compounds, and they are also capable of being dyed with aniline colors. They may be machined, tooled, tapped, and buffed, like hard rubber and celluloid. All are resistant to the ordinary conditions of everyday use and wear, but one important limitation to the usefulness of some of these Protal compounds is their susceptibility to the solvent influences of water and of other chemical reagents. This objection may be largely removed by subjecting this material to the action of a coating body or bodies which fill the molecular spaces existing in the structure of the material, for instance, by the use of formaldehyde or resins. In case use is made of resins it would appear that the material produced must necessarily be open to the same objections as were stated by me in referring to the shellac substitutes for rubber, that is to say, the oxidization of the resins. And this is true; where resins are used oxidation takes place. I am glad, however, to be in a position to state to you that, as it has been found possible to entirely dispense with the use of resins, this objection has been entirely overcome.

You will probably all remember the most interesting papers which were read last year before the American Chemical Society and

other scientific institutions, by Dr. L. H. Baekeland, announcing his remarkable discovery of a method of producing condensation products of phenol and formaldehyde. Immediately upon Dr. Baekeland's announcement, it at once became apparent to me that such a condensation product of phenol and formaldehyde, in the forms announced by Dr. Baekeland, was the material which I had so long sought and which would, when used in connection with Protal, produce a compound capable of manipulation like rubber and yet be entirely free from all the objections which had been urged to the use of a resinous body, because as you know a condensation product of phenol and formaldehyde is not a resin, as this term is generally understood. It does not saponify at all.

I am glad to be able to now show you samples of this material, known as Protal-Bakelite.

I want to show you first of all the two components. Here is the Protal in the form in which we use it—a finely ground powder. This is a vegetable-albumin. Here is the specimen of the "Bakelite." Dr. Baekeland also produces this in a transparent form. This little rod is pure "Bakelite." It was poured, when in a molten condition, into a test tube. It partakes very much of the nature of amber, and lends itself beautifully to the manufacture of jewelry and pipe-stems. It picks up paper and has essentially the properties of amber. To produce Protal-Bakelite, these two substances are intermingled most intimately and this powder results. This sample happens to contain 50 per cent of each of the ingredients.

You will all agree that twenty-five years ago no one would have believed that it were possible to transmit messages without wires, nor would one have believed that it were possible to photograph the internal organs of the body.

I have no doubt, therefore, that there may be skeptics when I announce my belief of definite reactions taking place between the individual components which form this material, reactions between a protein body and the condensation product of phenol and formaldehyde. In proof I offer the resultant materials. You certainly will recognize that the materials presented to you are entirely defferent from the elements entering into these products; samples of these individual components are herewith also submitted.

The reactions between the Protal and the condensation product of phenol and formaldehyde take place in the presence of heat, or of heat and pressure, and the product evidences that such reac-

tions, be they chemical, physical, or chemical and physical both, have taken place.

Protal-Bakelite, like Protal, may be combined with a large variety of substances, that is to say, combined in the physical sense. A large variety of substances may be added, as loading material, the material used as a load depending entirely upon the use to which the final product is to be put; as, for instance, in the production of an insulator, the best results can be obtained by the introduction of mica, asbestos, or both.

Where it is desired to increase the tensile strength of the product for use in such situations where it is to stand severe mechanical blows constantly applied, as, for instance, in pump valves, I have found it desirable to add asbestos or any other fibrous materials which are not readily decomposed by gases, acids, steam, oils, etc.

Where the material is to be used for molding operations there may be added to the Protal-Bakelite any material which will increase its primary plastic characteristics, as, for instance, paper pulp, wood flour, cellulose or, preferably, non-structural cellulose, these ingredients allowing very sharp impressions to be given to the material.

Protal-Bakelite compounds, in consequence of the great resistance which they exhibit toward nearly all chemical solvents, the high dielectric strength which many of these compounds possess, their hardness and ability to take a high degree of polish, are particularly well adapted for many purposes and uses for which hard rubber and hard-rubber compounds are at present almost exclusively employed.

In order that the process of manufacture of Protal-Bakelite compounds may be more readily understood, it may be well to recall here to you, in brief, the various forms of Bakelite and their respective properties, as before mentioned, these data being based on the information published by Dr. L. H. Baekeland, the inventor of this most interesting and valuable synthetic product, Bakelite.

Bakelite is produced in three grades, A, B, and C. Grade A can be obtained in a semifluid form which is known as Liquid "A." The consistency of this preparation is about that of molasses; slight warming renders it more fluid and prolonged heating at from 60° to 70° C., generally thickens it to a pastelike condition.

Solid "A" presents the appearance of a brittle, irregular, opaque, translucent mass having approximately the consistency and brittle-

ness of ordinary rosin. It can be produced in a form which melts at 40° C., or under, and in a form which melts at much higher temperatures, even above 100° C.

It is attacked by hot water and is entirely liquefied by heat, that is to say, it is still a fusible body. It is soluble in caustic soda, in acetone, and in a mixture of acetone and alcohol. Heating Solid "A" for some hours at a temperature of about 70° C. changes it into Form "B" this change being accompanied by shrinkage in volume.

In Form "B" Bakelite still softens under heat and becomes of a rubber-like consistency. However, it no longer melts. Under high pressure it softens, fuses, and welds together perfectly. It is insoluble in all solvents; acetone and phenol may cause it to swell somewhat, but they do not dissolve it. It is not attacked by hot water.

Heating at temperatures above 80° C. for a considerable length of time, or heating at very much higher temperatures, as from 160° to 180° C., or even higher for a shorter time, transforms Form "B" into Form "C." Generally speaking, the higher the temperature employed the shorter the time necessary to effect the transformation from a given form of Bakelite into the next succeeding form. Transformation of Form "B" into Form "C" is also accompanied by shrinkage, which is, however, much less pronounced than the shrinkage which occurs in the transformation of Form "A" into Form "B."

Form "C" is the final form to which Bakelite can be carried. In Form "C," Bakelite is no longer a plastic; it can no longer be melted; it can resist temperatures up to 320° C., in some cases up to 400° C; it is not attacked by boiling water, by steam, nor by water and ammonia when heated in an autoclave at 200° C., or above. Bakelite in Form "C" is a hard, structureless mass which may be produced either transparent or opaque. In color it ranges from a pale amber yellow to a dark ruby or brown. It is harder than shellac, hard rubber, or celluloid, but it is not flexible. It withstands all solvents and chemical reagents; it resists boiling water, steam, and superheated steam and the action of oils; it is resistant to boiling 10 per cent sulphuric acid and cold concentrated sulphuric acid, but chars in boiling concentrated sulphuric acid. It withstands hydrochloric acid and chlorine gas very well, but it seems to be attacked by bromine, and it is also attacked by concentrated nitric acid. At the temperature of melt-

ing glass it chars and carbonizes without entering into fusion; it is tasteless, odorless, and an excellent insulator of heat and electricity.

In view of some confusion on this point, it may be well to emphasize the fact that the three forms of Bakelite—A, B, and C, are absolutely distinct forms, and that one will not pass into the other merely by the lapse of time, but will do so only when the necessary physical conditions are provided to accomplish the change, that is to say, A remains A, B remains B, and C remains C, unless the physical conditions necessary to effect the transformations are provided. It should also be clearly understood that B is an anhydride of A, and that C is a polymer of B.

Now, coming to the question of the manipulation of Protal-Bakelite, this material may be produced in three forms:

(1) A plastic form, which may be readily molded;

(2) A semiplastic form capable of a certain amount of molding or impression and

(3) A hard, permanent form. The first two forms are susceptible to the action of heat and steam, and certain chemical reagents which would tend to change their form and destroy them.

In its final form, that is after subjection to the final treatment, bakelizing, i.e., heating under a pressure sufficient to prevent dissociation and resulting sponginess, the material is not susceptible to the action of the atmosphere, steam, oils, gases, acids, etc.

Objects can be produced directly by filling the powder into the molds, and subjecting it to the proper temperature and hydraulic pressure. On the other hand, we can press the powder into a preliminary form by applying hydraulic pressure at a low temperature. Placed in a mold and using a higher temperature, and of course again subjected to hydraulic pressure, the material can then be shaped into any form desired. There is still another form of our material known as "Bakelite-Paper," or as "Protal-Bakelite-Paper," in which the material is rolled out into very thin sheets, like paper, which can then be placed in molds and pressed.

Without going into details as to manipulation, I would state that this material may be rolled, pressed, molded, shaped, or otherwire manipulated, as is the case with hard rubber; that it has a high polish; that it will meet the requirements of articles produced from hard rubber, and, furthermore, that this product is not open to the most serious objection to hard rubber, i.e., it is not subject to oxidation and to all that that implies.

It may now be of interest to give a brief survey of some of the properties of Protal-Bakelite compounds, considering first of all such compounds which consist of 50 per cent each of these components.

The specific gravity of these compounds is practically 1.36. As determined by the McKenna Laboratories, they exhibit a tensile strength of 2000 pounds per square inch, and a crushing strength of over 60,000 pounds per square inch. On immersion in water, steam, machine oil, cylinder oil, acetone, alcohol, sulphuric acid, acetic acid, turpentine, benzine, and dilute solutions of sodium carbonate and ammonium hydrate, this material displays absolute indifference to all of these reagents. A plate of the above composition was exposed in the cabinet of a high-power medical electric machine generating between 300,000 and 400,000 volts, for over three months, and was not attacked by the ozone, or whatever the oxidizing components of the atmosphere in the cabinet may have been. Hard rubber, under these conditions, is very seriously affected. Subjecting Protal-Bakelite to actively boiling water for some hours produces no effect beyond a lightening in color; immersion in water at ordinary temperatures for months produces no deterioration whatsoever.

It thus appears that Protal-Bakelite possesses the following advantages over hard rubber: It does not soften by heat, as rubber does—in fact, Protal-Bakelite in the making may be said to be frozen by fire; it is not attacked by oils, grease, or the fats; it is not attacked by oxygen and ozone, and, as it contains no sulphur, the possibility of the formation of sulphuric acid, a very serious matter indeed in the construction of delicate electrical measuring instruments, is entirely obviated.

As far as the dielectric strength of pure Protal-Bakelite compounds of varying percentage-composition is concerned, tests of record made by the Electrical Testing Laboratories, New York City, have shown, among many others, the following values:

Protal. Per Cent.	Bakelite. Per Cent.	Volts per Mil.	Volts per Mm.
90	10	125	4921
80	20	145	5709
70	30	160	6299
60	40	227	8937
50	50	230	9055

It should be remarked that these tests were performed on samples as produced, and without having subjected the same to subsequent baking; such baking would undoubtedly have materially raised these values. Concerning the tensile strength of pure Protal-Bakelite compounds, this was found to range from 1190 to 2170 pounds per square inch. Among compounds of Protal-Bakelite with other ingredients, some possess a tensile strength of over 3000 pounds per square inch, and from the many tests of record of their dielectric strength made by the Electrical Testing Laboratories, the following may be quoted:

	Volts per Mil.	Volts per Mm.		Volts per Mil.	Volts per Mm.
1	227	8937	8	252	9921
2	227	8937	9	330	12,992
3	232	9134	10	380	14,961
4	235	9252	11	450	17,716
5	248	9764	12	550	21,653
6	252	9921	13	660	25,984
7	252	9921			

Uses. After what has been said, it would appear unnecessary, even if it were not practically impossible, to enumerate all of the many uses to which these new products can be put in the arts, and it must therefore suffice to indicate but a limited number of articles which can be advantageously made therefrom. To this end, it would seem desirable to adopt some rough method of classification based upon the special physical demands made upon these compounds in the various industries in which the compounds will be used.

Considering then, first such articles wherein tensile strength, toughness, and resistance to the ordinary conditions of everyday wear and tear are the qualities called for, mention may be made of:

Bodkins, buttons, checkers, chessmen, children's building blocks, cup plates, dominoes, door knobs, furniture castors, key tags, moldings of all kinds, panels, pencil holders, phonograph records—both disc and cylindrical—piano keys, picture frames, roller-skate wheels, rulers, shoe arches, shoe-box tips, shoe trees, spools, table tops, telephone receivers and transmitters, thread-drawing bobbins, etc.

Among the numerous articles in which, in addition to the qualities above mentioned, resistance to the influence of hot and cold

water, steam, and chemical reagents is demanded, there may be named:

Battery-jars, bushings, fountain pens, gaskets, grips for bicycles, guns, and pistols, handles for umbrellas, guns, cutlery of all kinds, inclusive of razors, dental and surgical instruments, lags, pump valves, rods, slabs, stocks of guns and pistols, shingles, trays—photographic and other kinds, tiles, tubes, washers, wheels—abrasive and polishing, etc.

Owing to the great range of dielectric strength which Protal-Bakelite compounds of different composition possess, they are of special value for electric insulation of every kind and description. Among articles used for this purpose there may be mentioned:

High-grade electric measuring instruments, ignition coils, linings for terminal boxes, magnet cores, magnetos, plates, strain insulators for trolley service, switch-boards, etc.

Where considerable flexibility is demanded of the material, other grades of Protal compounds must be employed; from these there can be made:

Automobile tires, bicycle tires, diaphragms, discs, doormats and runners, heels and soles, horseshoe pads, interlocking tiles, plumbers' force cups, valves—soft and semihard—weather strips, etc.

In presenting to you this outline of the manufacture, properties, and uses of these new products destined for use in the arts and industries, the speaker cannot allow the opportunity to pass without expressing his obligation to, and most sincere appreciation of, those men by whose unselfish, devoted assistance and support this work has been carried to its present stage.

To Dr. L. H. Baekeland he is most deeply indebted for the ever-ready, friendly counsel and co-operation which Dr. Baekeland and his assistant, Mr. Nathaniel Thurlow, have given so freely and cordially in the development of Protal-Bakelite; to his associates in the work, Mr. K. B. Millett, Mr. F. I. Congleton, and Mr. H. Swan, he would express his most cordial appreciation for their untiring efforts and helpful assistance.

DISCUSSION

President McKenna:

We would like to hear what the members have either to say or to inquire about Portal, and Dr. Wiechmann will duly reply to them.

Mr. Sadtler:

I would like to ask the approximate cost of the "Protal-Bakelite."

Mr. Wiechmann:

That question is one that I will have to answer with considerable discretion. All I can say is this: The material is, of course, intended to take the place of hard rubber. The cost of it compares extremely favorably with the present price of hard rubber. The actual cost for a given order would, of course, vary with the size of the order, and above all, with the grade of materials used. The fillers used with "Protal-Bakelite" vary much in cost, and an estimate would have to be made for any particular object called for.

Mr. Linder:

Is it necessary to use a filler?

Mr. Wiechmann:

Oh no, not at all. Only about 30 per cent of the samples on the table contain fillers.

Mr. Linder:

If you do not use any fillers at all, the price is cheaper than hard rubber?

Mr. Wiechmann:

Decidedly.

Mr. Lips:

How does the price of the elastic "Protal" compare with the price of ordinary rubber?

Mr. Wiechmann:

The difference is not so great, when we have to employ rubber. We have obtained excellent results with reclaimed rubber, 50 per cent, combined with "Protal" alone.

Member:

I assume that everything will ultimately be known as to the material.

Mr. Wiechmann:

The situation is fully covered by patents. Even now, nearly all have been issued.

Mr. Mayer:

I would like to ask if "Protal" has been tried as a substitute for gum in varnish.

Mr. Wiechmann:

No, it has not. I do not think it will lend itself to that at all. But Dr. Baekeland with his "Bakelite" produces an excellent varnish, also a material for the impregnation of wood. "Bakelite" may really be regarded as a synthetic Japanese lacquer. A block of wood impregnated with "Bakelite" is equal in hardness and durability to teakwood.

Mr. Lips:

A mixture of "Protal" and "Bakelite" would have to undergo pressure and heat in order to solidify, would it not?

Mr. Wiechmann:

All materials made of "Protal" and "Bakelite" are formed under simultaneous application of heat and pressure.

THE DEVELOPMENTS OF CHEMICAL INDUSTRY IN CANADA

By J. A. DE CEW

Read at the Niagara Falls Meeting, June, 1910

In bringing before this Institute a few facts with reference to the chemical industries now existing in Canada, the intention of the writer is not to attempt to adequately cover the subject either from a historical, statistical, or technical standpoint; because consistent treatment from any of these viewpoints would involve quite a serious undertaking, in spite of the facts that many of our chemical industries are relatively recent, and that as a country we are but beginning to enter upon this field of manufacture. As each writer, however, adds to the technical records the general data that may come within his experience, we may trust that in time a broader appreciation may be obtained of what is now taking place in our rapidly developing country.

The more recent published data relating to the above subject may be found in a paper read by Professor W. R. Lang before the Canadian Section of the Society of Chemical Industry, on May 6, 1903. With these facts before us, it is the aim of the present writer to convey some idea of the progress and developments that have since taken place.

Already there have been many readjustments of conditions of manufacture and centers of production and control. The rapid development of the railroads, and the iron and steel industries, have had their influence on the production of explosives, sulphuric acid, etc. The developments in the manufacture of cellulose have absorbed the production of saltcake, once a drug on the market. The developments of water powers, from which emanate the electro-chemical industries, have not yet affected, but may before long, the importation of the alkalies.

Without attempting to include every chemical product pro-

duced or to touch the field of metallurgical developments, which could only be described by a special student of these products, we might select the following products as being those which hold at present the largest interest in our chemico-industrial growth. These are:

Sulphuric acid, alkali and allied products; coal tar and ammonia; explosives; fine chemicals; wood distillation products; petroleum; salt; milk; sugar; starch; rubber; glue; paints; fertilizer; glass; beverages; soap and glycerine; calcium carbide and electrochemical products; wood cellulose products; Portland cements.

Sulphuric Acid. By far the largest manufacturers of this product in Canada are the Nichols Chemical Co., with works at Capelton, Que., Sulphide, Ont., and Barnett, B. C. The plant at Capelton was erected about 1890 and was operated by the chamber process until about five years ago, when this was entirely replaced by a contact process plant of three units. The plant at Sulphide was erected three years ago and consists of a one-unit contact plant, supplied with electric power. Another unit is about to be added to this installation. The plant at Barnett, B. C., has been erected one year, and consists of one unit of the contact system using Japanese sulphur as a raw material. Both of the eastern plants burn pyrites, of which there are large quantities in Ontario, Quebec and Newfoundland.

There are but two other works making sulphuric acid, and these are located at our extremes at East and West. The Dominion Iron & Steel Co, at Sydney, N. S., produce sufficient acid, by the chamber process, to make 25 tons of sulphate of ammonia per day. With their present plans for enlargement this plant will probably soon be doubled. At Victoria, B. C., the Victoria Chemical Company also produce sulphuric acid which alone, with the plant at Barnett, supplies the requirements of the explosive manufacturers of that province. The Nichols Chemical Co. are also manufacturers of hydrochloric and nitric acids and Glaubers salt.

Alkali. At present there are no alkali manufacturers in Canada, due partly to the fact that the markets would require a production on a smaller scale than is customary and that these products enter the country free of duty. The indications are, however, that something will be done in electrolytic alkali in the

near future, on account of the economic production in small units at the point required.

The Canadian Salt Co., at Windsor, Ont., will soon be making caustic soda by an electrolytic process, and will have a production of about 8 tons per day of 24 hours.

Coal Tar and Ammonia. By far the largest amount of tar and ammonia is produced at Sydney by the Dominion Iron & Steel Co., which distill about 2000 tons of coal per day. The tar products are all refined and marketed by the Dominion Tar and Chemical Co., while the ammonia products are disposed of by the Steel Co. in the form of sulphate of ammonia, most of which is exported.

The remaining tar and ammonia products are produced by the various gas works, which sell their tar and pitch to the manufacturers of roofing paper, while their ammonia is absorbed to about a 20 per cent solution and sold either to the Michigan Ammonia Works of Toronto or to the Dominion Tar and Ammonia Co. of Hamilton. Both of these firms produce anhydrous ammonia, the latter having entered the field within the last two years.

Another development in tar and ammonia products will soon be realized upon the erection of a large number of by-product coke ovens, by the Algoma Steel Co. of Sault Ste. Marie. This firm has decided to extend its production of coke and has disposed of the charcoal plant formerly operated by them.

The by-product coke oven plant, now under construction, is to be completed by January, 1911. It will consist of 110 ovens, Koppers type, the contractor being H. Koppers of Essen, Germany. These ovens are to be 37 ft. long, 19 ins. wide and 10 ft. high, each holding a charge of 12.75 tons of coal. The estimated yield is 76 per cent, or 9.69 tons of coke per oven. The time of coking is 21 hours and total capacity of plant 1100 tons of coke per day of 24 hours. The annual consumption of coal will be 505,000 tons, which will be brought from the company's collieries at Cannelton, W. Va.

The production of by-products from this plant will be as follows:

Tar, 27,000 tons per year; sulphate of ammonia, 5400 tons per year; surplus gas, 7,500,000 cu.ft. per 24 hours. This will be used at the steel plant for heating furnaces, soaking pits, and fuel, instead of the coal now used.

The tar products of this plant will all be refined by the Dominion Tar and Chemical Co. in a plant similar to that operated by them at Sydney, N. S., which they propose to erect during the present year. Their products consist of briquetting pitch, creosoting oils, and light oils. The company proposes to spend $75,000 in this plant and employ from 20 to 30 men.

Explosives. The largest manufacturers of nitroglycerine and explosives in Canada are the Hamilton Power Co. of Montreal, with works at Belœil, Windsor Mills, Que., and Nanaimo, B. C. The nitro powder is made at Belœil and the black powders at Windsor Mills, while at Nanaimo both grades are produced. The Ontario Powder Co. are also manufacturers of nitroglycerine at Tweed, Ont., and the Northern Explosives Co. at Rigaud, Que. In the East, we have the Acadia Powder Co. at Halifax, N. S., and in the West there are two other works—the Giant Powder Co., situated near Victoria, B. C., and the Western Explosives, Ltd., at Rowen Island, B. C. The present production of these works may be estimated from the fact that during the year ending March, 1910, the amount of glycerine used for explosive purposes was 3,947,000 lbs. Without doubt, however, the productive capacity of these works will be considerably over this figure.

Fine Chemicals. The manufacture of fine chemicals in Canada is of but recent origin—dating back only to 1906 and 1907. The National Drug and Chemical Co. of Canada established a manufacturing laboratory in Montreal in 1906, and since then have been manufacturing such products as salts of iodine, bismuth, lithia, etc. They also manufacture hydrogen peroxide, hexamethylenetetramine, iodoform and many of the citrates. In the year 1907 the Chemical Laboratories, Ltd., of Toronto, under the direction of Professor Wallace P. Cohoe, commenced the manufacture of such products as iodides, hydrogen peroxide, mercurials, bisulphides, phosphoric acid, lime, sulphur, lead arsenate, silver and gold salts. Both of the firms have been quite successful in this work, and are continually adding new products to those already mentioned. The John Cowan Co. of Montreal are also manufacturers of liquid ammonia products.

Wood Distillation Products. The successful development of this industry is due largely to the efforts of one firm, namely The Standard Chemical Co., which is the oldest and largest manufacturers of these products. They operate six works for the

production of the crude acetate and alcohol, the location and capacities being as follows:

South River	48	cords per day
Fenelon Falls	22	"
Longford	60	"
Cookshire	48	"
Fassett	48	"
Sault Ste. Marie	160	"

There are four smaller firms that commenced operations in the last few years, producing crude products. These are:

The Wood Products Co. at Donald	48	cords per day
Dominion Chemical Co. at Weedon	24	"
Gall Chemical Co. at Mount Tremblant.	36	"
Algoma Lbr. and Chem. Co., Parry Sound	32	"

Altogether, then, there are ten plants distilling over five hundred cords of hardwood per day. The productive capacity in wood alcohol of 82 per cent is equivalent to about 1,500,000 wine gallons per year, while the domestic consumption of this article will not exceed 250,000 gallons. Nearly all of the crude acetate produced is exported in that form.

A refining plant for working up a portion of these crude products is operated at Montreal by the Standard Chemical Co. This works produces acetic acid, acetone and formaldehyde. The value of the acetic acid produced will be about $30,000 per year. The acetone plant has a capacity of one and a half tons per day, but the domestic consumption will be about 36,000 lbs. per year. The formaldehyde plant produces 30,000 lbs. operating six months in the year. About 20 per cent of this is exported. The production of wood distillation products could be greatly increased in Canada, but with a small home market the industry requires the most careful management in producing for a foreign market in which there is severe competition with the overproduction of Germany, Austria and the United States.

It is also difficult to find a market for the charcoal, although a moderate domestic demand has been developed by selling it in paper bags for kindling. The overproduction has up to the present been used in the manufacture of charcoal iron, but the high quality of this product is not sufficiently appreciated by the

consumers, and it is hard to say what will be the actual value of the charcoal in the future as a fuel for the blast furnace. The competition with the government denatured alcohol has also depressed this product and at present the price in Canada is fifty cents per imperial gallon, while at one time one dollar was obtained. As this industry is now adopting newer methods of fuel economy it will without doubt be able to adapt itself to changed conditions and long remain a profitable and firmly established industry.

Chemically pure acetic acid is also made in considerable quantity by the Canada Paint Co., of Montreal. There is another plant producing products by destructive distillation by using a different raw material. This is the Canadian Turpentine Co., with works at Barry's Bay, Ont., in which the resinous stumpwood of the Norway pine is distilled for the production of wood tars, oils and turpentines. A scheme for the destructive distillation of resinous wood by means of the application of electric heat inside a vertical retort without passing through the walls is now being exploited by the Electric Turpentine Co. of Canada, under the patents of F. T. Snyder. The project is being financed by Vancouver capitalists, and they propose to manufacture turpentine, tar, oil, rosin, charcoal and pitch.

Petroleum. The refining of petroleum is carried on at Petrolia, Ont., by the Canadian Oil Co., the capacity of the plant being 60,000 bbls. per month. The Petrolia oil field has been a constant producer for many years, but the recent discoveries of oil in the counties of Essex, Kent and Lambton are such as to lead us to expect the establishment of a plant for the refining in the newer field. The evidences of oil in Northern Alberta and the Peace River country, are such as to indicate many openings for the oil industry in this region, while the rich deposits of oil-shale in New Brunswick and Nova Scotia are only awaiting the proper exploitation of a large and profitable industry.

Salt. There are eight works producing salt in Canada, the value of the total yearly production being about $500,000. The largest firm supplying the Canadian market with refined salt is the Canadian Salt Co., with works at Windsor and Sandwich. In the Windsor plant fine table salt of 99.80 per cent purity is produced, three large vacuum pans being used in this work. The capacity of the Sandwich plant is about 400 bbls. per day, while

at Windsor 1000 bbls. per day can be produced. The Dominion Salt Co. of Sarnia also produces salt by the vacuum process and has a capacity of about 500 bbls. per day.

Other producers who use open pans for draining are :

The Western Salt Co. of Moortown, Ont.....	125	bbls. daily.
The Western Canada Flour Mills Co., Goderich	250	"
John Ransford, Clinton	100	"
Peoples Salt and Soda Co., Kincardin	100	"
Grey, Young & Sparling, Wingham.	100	"

As all the brine from the Canadian wells is of very high purity, it easily makes with proper plant and refining treatment the highest grade of table salt.

Milk. In the dairy districts of Canada, which have become famous for their cheese production, the manufacture of condensed milk has grown to be an industry worthy of some consideration. The increased demand for canned milk products in the mining and lumbering districts of the North and West has resulted in the establishment of several new plants for making this product. There are six establishments in Ontario, three in Quebec and three in Nova Scotia, the total invested capital of which will be about $800,000.

In spite of the fact that the manufacturers of this product appear to be unfamiliar with the advances made in methods of vacuum evaporation and are at present almost the only users of the old form of copper-coil pans, the industry as a whole seems to be in a very profitable condition at present. In this we have a very interesting case of the technical inertia of a trade which is due very largely to the protection surrounding a working process that, in industries of a larger magnitude, has become almost extinct.

Sugar. The refining of sugar in Canada is an industry of considerable relative magnitude, as there are eight refineries with an invested capital of $13,500,000 and producing annually from 18,000,000 to 19,000,000 bbls. of finished products. The largest refinery is that of the Canada Sugar Refining Co. of Montreal, capitalized at $3,000,000 and having a capacity of 2000 bbls. per day. The St. Lawrence Sugar Refining Co. of Montreal, with a similar capital, has a capacity of 1500 bbls. per day. In Nova

Scotia the Acadia Sugar Refining Co. of Halifax, capitalized at $2,000,000, has a capacity of 800 bbls per day.

The above works refine raw cane sugar, while in Ontario there are two works for the production of beet sugar. These are the Ontario Sugar Co. at Berlin and the Dominion Sugar Co. at Wallaceburg. These factories are permitted to import raw beet sugar for refining during the winter months. In the West, the Knight Sugar Co. of Raymond, Alta., has been very successful on beet sugar, and the British Columbia Sugar Refining Co. of Vancouver, B. C., in the refining of cane sugar, which is chiefly imported from the Fiji Islands.

Starch. In the production of starch there are ten establishments, with a capital of $1,351,000 and producing products valued at $1,500,000. The Edwardsburg Starch Co. of Montreal are the largest manufacturers, with a capital of $600,000 and works at Georgeville and Cardinal, and manufacture practically all forms of starch products. There are four smaller works in Prince Edward Island, and in Ontario there are the Brantford Starch Works and the St. Lawrence Starch Co. of Port Credit.

Rubber. The rubber products of Canada are mainly produced by the Canadian Consolidated Rubber Co., with works at Montreal, Berlin, Granby, and Port Dalhousie. The independent companies are the Gutta Percha Rubber Co. of Toronto, the Durham Rubber Co. at Bowmanville, and the Miner Rubber Co. at Granby, which has just been completed.

The most interesting process in the rubber industry to the chemical engineer is that of the recovery of waste rubber. It is well known that most of the processes for accomplishing this are based upon the hydrolytic action of mineral acids on cellulose, and the resultant solution or destruction of the fiber. This process, however, does not remove the free or combined sulphur, and in consequence the alkaline process, known as the Marx process, has some distinct chemical advantages, especially for tires. This process has been in operation for some time at one of the Canadian works and is, in several ways, an interesting case of the isolation process. The process rests upon the solvent action of caustic soda on cellulose, and is in this respect analogous to the alkaline processes of producing cellulose from lignocellulosic material. The latter processes, however, have developed to a high state of efficiency in design, production

and recovery, while the former is still in the embryonic stage of a new process that has not yet been obliged to absorb the experience of a sister industry.

Glue. As the production of glue is closely related to the packing industry, the census figures of the independent factories will hardly cover this product. The chief works for glue alone are the Canada Glue Co. of Brantford, The Berlin Glue Works of Berlin, and F. C. Marquis of Quebec, while several of the large packers handle their own glue stock. The value of glue products produced will represent over $400,000, while large quantities are also imported.

Paints, Varnishes and Oils. Among the producers of raw materials for this industry, we have concerned in the manufacture of linseed oil, the Canada Linseed Oil Mills and the Sherwin-Williams Paint Co., of Montreal, and the Dominion Linseed Oil Co. of Toronto. The manufacturers of white lead are the Carter White Lead Co. and the Brandram-Henderson, Ltd., of Montreal, the latter having erected a large plant within the last two years. Paris green and chromates are made in considerable quantity by the Canada Paint Co. of Montreal. In manufacturing paints and varnishes there are 25 establishments with a capital of over $3,000,000 and producing products valued at over $4,000,000. The largest manufacturers are the Sherwin-Williams and the Canada Paint Co. of Montreal.

Fertilizers. Although a large amount of fertilizer products are made by various industries in Ontario and Quebec, yet practically all of the finished product ready for the soil is made in the province of Nova Scotia, which is no doubt due to the proximity of the fish-packing industry. There are six well-established fertilizer firms in this province with a capital of about $400,000.

Glass. There are seven establishments interested in the manufacture of glass, the chief of which are the Diamond Flint Glass Co. of Montreal, the Sydenham Glass Co. of Wallaceburg, Ont., and the Humphreys Glass Co. of Trenton, N. S. The capital invested in this industry is about $860,000 and the products about $1,500,000.

Liquors and Beverages. In the Canadian census of 1906 the following figures are given with regard to the volume of this industry, which show that it has a very important place among

others which depend upon chemical changes in their conversion.

	Establishments.	Capital.	Value of Product.
Aerated and mineral waters	64	$1,809,406	$1,949,951
Liquors, distilled	9	10,209,000	2,343,000
Liquors, malt	89	12,688,948	8,444,177
Liquors, vinous	7	684,204	254,000
Malt	4	738,300	936,961

Soap and Glycerine. Within the last year another movement has begun in the soap trade which for a few years previous was not very active. Between 1900 and 1905 there was an increase in this trade of nearly 50 per cent and, in the last census reports of 1905, the total number of factories was 20, with a capital of $2,600,000 and a production of $3,000,000 worth of soap annually. From the soap trade there is a production of about 600 tons of crude glycerine and about half of this is refined in Canada. There is but one refining plant, and that is operated by the Sunlight Soap Works at Toronto. The total amount of crude will be shortly increased, owing to the fact that several new recovery plants are now being installed.

Calcium Carbide and Electro-chemical Products. It is perhaps due to the economic availability of our water power developments that the growth of the carbide industry has taken place in Canada simultaneously with that of other countries. At present we have four very modern works with a total productive capacity of about 20,000 tons of carbide yearly.

The first manufacturers in the field were the Wilson Carbide Co. of St. Catherines, and the Ottawa Carbide Co. of Ottawa. Both of these works make ingot carbide, the St. Catherines plant having a capacity of 2500 tons, and the Ottawa plant 4000 tons yearly. The largest plant in Canada is that of the Shawinigan Carbide Co. of Shawinigan Falls, which commenced operations in 1904 and has now a capacity of 10,000 tons per year, all of which is tap carbide. The electrical equipment of the Shawinigan Carbide Company consists of four 750 K.W. transformers and twelve 300 K.W. transformers for supplying current to the furnaces and three 175 K.W. transformers for use in connection with the motor equipment. The Ethinite Company of Niagara Falls,

Canada, is a producer of carbide, their works having been recently established.

The natural result of further developments in this industry will be the production of calcium cyanamid, which is now being manufactured at Niagara Falls, Canada. This product may some day be the connecting link uniting the acetylene and cellulose industries. One way of getting almost pure nitrogen is the removal of the oxygen of the air by combustion with sulphur, although the present source of nitrogen is liquid air.

In the electrochemical field the largest plant in Canada is that of the Northern Aluminum Company at Shawinigan Falls. In these works metallic aluminum is manufactured from the oxide by the Hall process. The refined oxide is brought to this point from the United States and after the metal is produced it is converted into wire and cable in the company's wire-drawing plant. This company has three mills for each of which 10,000 H.P. is available. It is here that the cable for our largest transmission work has been produced. The Electro Reduction Co. of Buckingham, Quebec, are manufacturers of phosphorus, using the local apatite as a raw material. The power developed at these works is about 2500 H.P.

Wood Cellulose Products. The production of cellulose in Canada has not developed to the extent that the raw materials available would justify, due very largely to a limited home demand and the low prices of foreign markets. With the prospects for a largely increased production in the manufacture of news paper, a simultaneous development in the manufacture of sulphite is also to be expected in the immediate future.

The manufacture of cellulose by the caustic soda process began in Canada about the year 1865, when the first mills were erected in the U. S., but very little advance has been made in this process until very recently, when the sulphite process was introduced. Within the last three years three mills formerly using caustic have gone over to the sulphite and two sulphite mills have been erected. This process seems to be supplanting the caustic process entirely as far as coniferous woods are concerned, although it does not follow that the industry will not again in part return to the use of caustic soda in the face of further developments. Experience seems to be that, where there has been intelligent introduction of foreign methods applied to home prac-

tice and experience, the results are very satisfactory while the detailed imitation of foreign plants does not properly serve our needs. The readjustments in this process are still going on, and we have not yet seen the final stage of development. By the end of the present year the production of sulphite fiber will probably reach 100 tons per day, the two largest plants being operated by the Brompton Pulp and Paper Co. of East Angus, Que., and the Quebec and St. Maurice Industrial Co. of La Tuque, Que.

In the production of sulphite, the latest plant established is that of the Canadian Pacific Sulphite Pulp Co. of Swanson Bay, B. C., which started last year with a production of 25 tons per day. This mill is making an excellent and strong fiber from the Pacific coast spruce and balsam. Another large plant recently started is that of the Anglo-Newfoundland Development Co. of Grand Falls, Newfoundland, with a production of 60 tons. The largest sulphite plant in Canada is that of the Riordan Paper Mills at Hawskbury, Ont., where the production is 110 tons per day. The same firm has a plant at Merritton, Ont., producing 30 tons per day.

Other plants now in operation are as follows:

Name.	Location.	Daily Capacity. Tons.
J. R. Booth	Ottawa, Ont.	60
E. B. Eddy Co.	Hull, Que.	50
Laurentide Paper Co.	Grand Mere, Que.	70
Miramichi Pulp and Paper Co.	Chatham, N. B.	50
Dominion Pulp Co.	Chatham, N. B.	20
Edward Partington Pulp and Paper Co.	St. John, N. B.	40
St. John Pulp and Paper Co.	St. John, N. B.	30
Jonquiere Pulp Co.	Jonquiere, P. Q.	10
Toronto Paper Co.	Cornwall, Ont.	10

The total production of these mills is something over 500 tons per day and the larger part of it is converted into paper in Canada for home and foreign trade. In all of the above mills the tower system is used for the production of the bisulphite liquors, with the exception of those at Ottawa and Jonquiere. In the latter the tank systems are used with caustic lime as a base.

There are two large mills not now in operation, one at Sturgeon Falls and the other at Sault Ste. Marie, Ont. These are likely to be reopened at any time for the present growing demand, in which case about 80 tons daily would be added to the present production.

An industry that is still in its inception but which is somewhat related to the sulphite process, is the production of ethyl alcohol from waste wood. The conversion to sugar is affected by means of sulphurous acid under fixed temperatures and pressures in a digester with an acid proof lining. Such a plant is now proposed for Parry Sound, Ont.

Portland Cement. The manufacture of Portland cement in Canada dates from the year 1891, when beginnings were made in a small way at Marlbank and Shallow Lake, Ont. The first year's production amounted to about 2000 barrels, and from that year in the rapid expansion of the industry is one of the most startling evidences of Canada's industrial growth. In 1891 the production was 20,247 bbls. while in 1893 it reached 31,924 bbls. and so on in like ratio until in 1901 it had reached a total of 350,660 bbls.

From 1901 the following figures give the rate of expansion of the industry.

Date.	Establishments.	Yearly Production.
1902	8	522,800 bbls.
1903	9	695,280 "
1904	11	880,871 "
1905	15	1,200,000 "
1907	..	2,436,093 "
1908	..	3,495,961 "

The production for the coming year will probably be about 5,000,000 barrels, while the plants now erected would be able to turn out if necessary about 8,000,000 barrels per year.

In order to show fully the present extent of the works now established, the following list is submitted, giving the name, location and daily capacity of each works.

PLANTS OWNED AND OPERATED BY THE CANADA CEMENT CO., MONTREAL

Name.	Location.	Daily Capacity.
Lakefield	Lakefield, Ont.	850 bbls.
Owen Sound	Shallow Lake	1200 "
Canadian	Marlbank, Ont.	1200 "
International	Hull, Que.	2000 "
Canadian	Port Colborne, Ont.	1800 "
Vulcan	Montreal, Que.	2000 "
Lehigh	Belleville, Ont.	2500 "
Belleville	Belleville, Ont.	1500 "
Lakefield	Montreal, Que.	1700 "
Alberta	Calgary, Alta.	1000 "

The following is a list of the smaller manufacturers.

Hanover	Hanover, Ont.	650 bbls.
Sun	Owen Sound, Ont.	500 "
Imperial	Owen Sound, Ont.	500 "
Grey and Bruce	Owen Sound, Ont.	300 "
National	Durham, Ont.	1000 "
Raven Lake	Raven Lake, Ont.	700 "
Ontario	Blue Lake, Ont.	500 "
Maple Leaf	Atwood, Ont.	500 "
Superior	Orangeville, Ont.	500 "
Crown	Wiarton, Ont.	750 "
Western Canada	Exshaw, Alta.	1800 "
Rocky Mountain	Frank, Alta.	500 "
Vancouver	Tod Inlet, B. C.	800 "

DISCUSSION

PRESIDENT MCKENNA:

This is a very valuable paper, as you will see from the masterly way in which the topics have been handled, and I imagine it will become a historical document. It should open our eyes to the extraordinary developments going on in this country, of which Americans know so little. I should like to hear a discussion of it.

DR. LIPPS:

I should like to ask what is the principal use of ammonium sulphate. Is it used for fertilizer?

MR. DE CEW:

There is very little market for fertilizer. The Dominion Iron and Steel Co. have to export nearly all of it. Being on the Atlantic coast they are able to do so. The internal consumption has not really commenced yet, and the production of other fertilizers will really have to find a market abroad. I do not know what the people who are making the nitrogen fertilizer do with their product, but I imagine there is very little demand for it in Canada.

DR. WIECHMANN:

What per cent of the sugar refined in Canada is obtained from the beet?

MR. DE CEW:

I have not the exact proportion, but as you know the refineries in Montreal and the Arcadia in Nova Scotia import cane sugar from the West Indies and the refineries on the Pacific coast from the Fiji Islands. There are only three or four more in Ontario and one in the middle West. Beet sugar is very much in the minority.

PRESIDENT MCKENNA:

The growth of the Portland cement industry mentioned by Mr. De Cew is in its way as remarkable as the growth in the United States, where about fifteen or sixteen years ago we thought we were producing a great deal when we turned out 1,000,000 barrels. Now the output is 60,000,000 barrels—an extraordinary growth in such a short period of time. There is no commodity in the history of the world that can show the growth in consumption all over the world that Portland cement does.

AVAILABILITY OF UNDERGROUND WATERS FOR MANUFACTURING PURPOSES*

Waters in New York State from Albany to Buffalo

By WM. M. BOOTH

Read at the Niagara Falls Meeting, June 24, 1910

Other conditions remaining approximately equal, very few large manufacturing concerns can compete successfully with others of the same kind, unless a large amount of good water is available at a reasonable price. If the plant is located on a large river or lake, where soft water can be pumped under low head to all parts of the plant, water conditions may become ideal, the expense remaining at its minimum.

Manufacturing districts are constantly increasing and demanding larger quantites of water. City supplies have to be resorted to in a greater degree than formerly and the annual expense for water may amount to many thousand dollars. Confronted by such conditions, the mill operator often decides to look for an underground supply. It is our purpose to furnish certain preliminary data that have been and may be used in such connection.

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*This preliminary paper outlines a water survey that I believe is needed throughout all manufacturing sections.

To my personal knowledge, expensive wells have been drilled in strata almost sure to result in failure. If it can be shown that certain general strata underlie a manufacturing plant, the type of water to be obtained can, with considerable accuracy, be predicted.

The analyses included are my own.

The method of grouping mineral salts is generally as follows: The mineral residue after evaporating 250 cc. to dryness at 212° F. and filtering, is examined for calcium and magnesium. These are considered carbonates. The filtrate is examined for soluble calcium and magnesium. Sulphur trioxide is combined first with soluble calcium, the excess with soluble magnesium and further excess with sodium. Chlorine is combined first with potassium, then with sodium, calcium and magnesium.

Underground waters are usually harder than those found on the surface. This has always been disadvantageous for boiler use and generally for technical use as well. However, many wells driven into granite and related rocks afford very soft water. Aside from hardness, well waters usually possess many advantages. They are free from mud and suspended vegetable matter and are usually uniform in quality and safe for drinking purposes. For moderate depths, well waters are cooler than surface waters on the average throughout the year, and, of still greater importance, their temperature is remarkably uniform. The annual cost of pumping from a good well is low, especially with a large boiler plant.

Water from expensive wells may be useless for any purpose. Calcium, magnesium, sodium and iron salts and hydrogen sulphide injure the quality of water. If heavily charged minerally, the well is usually discarded. We present herewith analysis of water taken from a well at Utica, N. Y., containing carbonates, sulphates and chlorides of calcium and magnesium, present in such quantity as to make the water useless for any purpose but that of fire. (See Table IX Utica Well, 1270 ft. deep.)

The importance of an available supply and the total inability to satisfy this demand in many localities have resulted in the publication of considerable literature relating to this subject. More recently government and State records have been made available so that one who wishes to look for water in a given locality has more or less accurate data at his command. These have often been supplied by well drillers who are not all geologists and may report that which exists only in fancy. The underlying strata to be found in manufacturing sections may include the following: (Table I, Col. 1). Water passing through or over these will hold in suspension or solution matter found in column 2 and is assigned to classes found in column 3.

To illustrate the service of geological records we make use of sectional maps covering that portion of New York State which is traversed by the New York Central Railroad and which contains many cities devoted to manufacturing.

Fig. I, New York State; belt from which samples have been taken. (From State Geological Map.)

Fig. II, Lower plate; section from Adirondacks to Lake Erie. (From State Report 1842.)

TABLE I

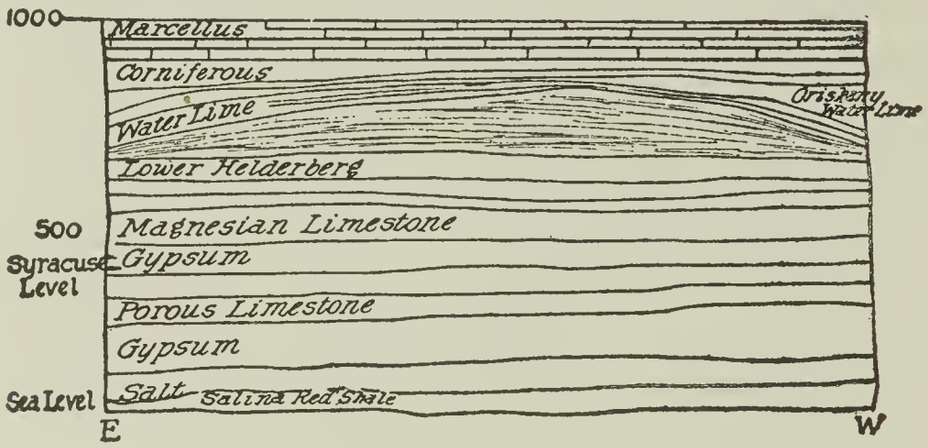
COLUMN 1	COLUMN 2	COLUMN 3
Peat	Vegetable acids	Brown and unsanitary with organic matter.
Marl	Carbonate of lime	Temporarily hard.
Clay	Alumina and carbonate of iron	Difficult to filter.
Sand	Potash, soda and silica	Soft.
Gravel		Soft or hard, depending on previous strata.
Quicksand	Silt	Difficult to pump.
Drift, including hard-pan, clay and gravel	Carbonates of calcium, magnesium and gypsum	Temporarily and permanently hard.
Limestone	Carbonate of lime	Temporarily hard.
Sandstone		Soft or hard, depending on binding material.
Dolomite	Magnesium and calcium carbonates	Temporarily hard.
Shale	Carbonates of calcium and magnesium with slight sulphates	Temporarily hard.
Gypsum	Calcium sulphate	Permanently hard.
Saline	Chlorides of calcium, magnesium and sodium	Permanently hard and encrusting.
Gneiss	Alkalies	Very soft.

Water from wells east and north of Utica are usually soft; those to the west usually contain much mineral matter.

Fig. III was prepared for this paper by Prof. T. C. Hopkins of Syracuse University. This is a section following the N. Y. C. R. R. It will be seen that the surface strata from Albany to Utica are very much broken but that Hudson River shale, Trenton limestone and Beekmantown (calciferous sand rock) are found throughout. From Utica to Lyons, Clinton and Salina shales predominate, while from Lyons to Buffalo are found limestones. The fact that the city of Rochester is further north than other cities of this group brings the Niagara limestone to an apparent apex.

Fig. IV shows a section of the Central New York belt from north to south. We include this as several well waters have been analyzed from this horizon. (Taken from Regents' Report, 1895.)

Fig. V shows a horizontal section from east to west through Onondaga County. As the altitude of the surface of the county along the railroad is about 400 feet, wells usually penetrate gypseous strata. (From same source as above.)



ONONDAGA COUNTY

Fig. 5.

Table II

GENERAL THICKNESS OF NEW YORK ROCKS

Prepared by Prof. T. C. Hopkins.

Onondaga limestone	168 ft. Buffalo.
L. Helderberg (Manlius, etc.)	180 ft.
Salina group, shales	1230 ft. Central New York.
Clinton (shales, etc.)	175 ft. Clinton; 81 ft. Rochester.
Niagara limestone (Lockport)	130 ft.
Medina-Oswego	620 ft.
Hudson River-Utica, etc.	1000 ft. Clinton; 3000 ft. near Albany; 950 ft. Rochester.
Trenton-Lowvelle, Black River	200 ft.
Beekmantown, Calciferous	2000 ft. to 450 ft. Little Falls.

Waters from these groups are usually highly mineralized, excepting the latter two.

This belt is composed mainly of sandstones, limestones and shales laid down by the primeval salt waters in the ocean bottom, on beaches and in marshes.

Granite is found at a depth of about 1200 feet at Utica and 3600 feet at Warner's Station on the New York Central Railroad, ten miles west of Syracuse. The dip is then 3000 feet in sixty miles or about fifty feet per mile. Upon this rock shelf the sedimentary rocks have been formed with a similar general slope westward and southward. As carbonates and sulphates of lime

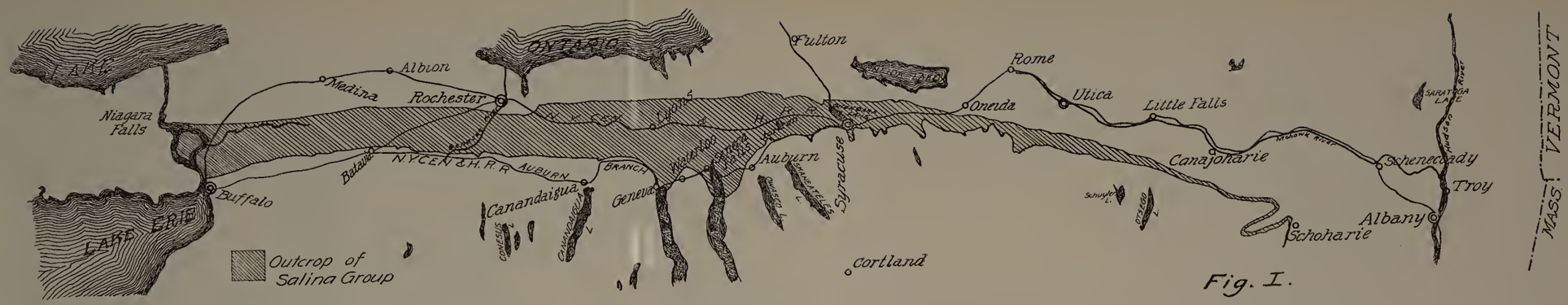


Fig. I.

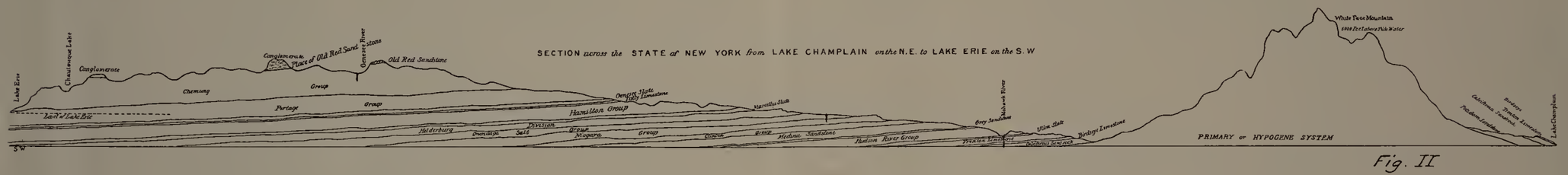


Fig. II

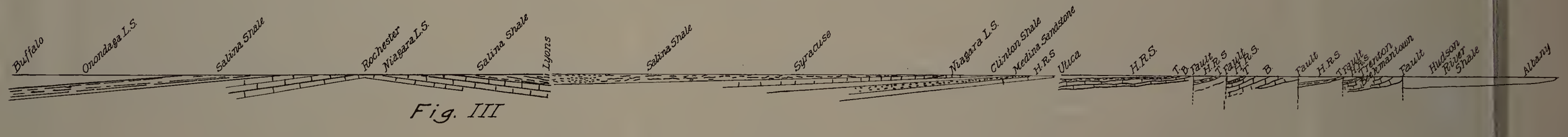


Fig. III

SECTION NORTH AND SOUTH THROUGH ONONDAGA COUNTY

Fig. IV

and magnesium are generally distributed, the temperature of the belt has at no time been greater than 200–300° F. With the recession of the sea, those salts, least soluble, first crystallized in bands, dykes and pockets. Carbonate and sulphate of lime were followed by sulphate of magnesium and chlorides of calcium, magnesium and sodium. Finally, these chlorides separated in rock form.

By chemical interchange, weathering, the action of organic matter and the decomposition of iron pyrites, a large number of common and rare minerals have found their way into water which flows from springs and is pumped from wells. New beds and pockets of soluble salts are constantly being uncovered and the mineral matter started toward the sea. An accurate knowledge of the strata underneath any locality must then be of great advantage to the manufacturer who looks for an underground water supply.

TABLE III

WELL RECORDS

Character Rock.	Depew, near Buffalo. Alt. 681 Feet.	Vernon, near Rome. Alt. 598 Feet.	Rome. Alt. 445 Feet.	Utica. Alt. 407 Feet.	Ilion. Alt. 392 Feet.
	Feet.	Feet.	Feet.	Feet.	Feet.
Drift	34	.....	125	48	195
Corniferous limestone, Salina shales	560				
Niagara limestone	200				
Shales	60				
Clinton group	30	115			
Red Medina sandstone	90	20			
White Medina sandstone	12				
Red shale	1164				
Oswego sandstone	75	445			
Hudson shale	.....	720	225		
Utica shale	630	300	300	447	280
Total	2855	1600	650	495	475
Trenton limestone	720	350	375	369	105
Birdseye limestone	.....	.....	60	.....	50
Calciferous sand rock	110	18.5	475	440	475
Laurentian rock	.....	.....	.....	55	30
	3685	1968.5	1560	1359	1135

Drilling. It is not always necessary to drill a very deep well to get a considerable quantity of water. Many manufacturing concerns with which we are acquainted are getting an ample supply from depths varying between 60 and 500 feet. It has been our experience that wells of less depth than the minimum mentioned are liable to surface contamination. In any event the preparation in connection with drilling a deep well should include a report by a competent economic geologist who must be familiar with existing strata as they are usually found in the locality and must acquaint himself with well records or other information that will be useful in connection with the proposed enterprise. The drilling of a well must be taken up with a thorough understanding that the matter is a business venture with a possible total loss of capital employed.

If a favorable report from the disinterested man is made the question of the kind of well to be drilled, its location on the property and related preliminary matter must be taken up with a practical well-drilling concern.

Four general types of well-drilling are as follows: bit, diamond drill, steel shot, jet. The anticipated strata will in large measure fix the type to be selected. This is largely a matter to be left with the well driller. It should be remembered that the larger the diameter of the well the greater the reservoir for water in case of emergency.

Having begun drilling operations a contract should be made with a competent chemist who should test the water found both in reference to quality and quantity while a record should be made of the exact depth under the surface at which the water occurs. It is of great scientific advantage to retain a record of any well. This can be done by the chemist or by the geologist if samples of the broken rock or other material are saved in small bottles.

If the water in quantity or quality is found to be insufficient the casing should be driven by these points and other sources looked for at a greater depth or in a new drill hole in other parts of the property. When a sufficient supply has been obtained this should be analyzed from a chemical and sanitary standpoint. In the meantime, the driller should not remove his tools. If the quality of the water is sufficiently satisfactory for use, its quantity must then be ascertained. If near the surface or con-

taining sand, a centrifugal pump may be employed, while, if the distance to the water is considerable, an air lift may be used temporarily at least.

It has been our experience that bacteriological tests should be made after water from a deep well has had time to recover from the pollution occasioned by drilling. Not all deep well waters are sanitary. Water from a 500 feet well recently drilled, contained colon bacilli and a total amount of 600 bacteria per cc. After one month of pumping this was reduced to 5 bacteria per cc. with no colon types.

Underground water formerly considered useless for boiler purposes is now successfully treated chemically. If a public supply costs more than seven cents per thousand gallons, moderately hard well water can be treated and furnished less expensively including depreciation of plant.

While the quality of surface water may vary from hour to hour, underground waters are usually very constant and are thus ideal for softening processes. With the same chemical supply for months and with large variations in the quantity of water used from a well 130 feet deep at Canajoharie, N. Y., the softened water has contained the following amount of calcium and magnesium oxides;

TABLE IV

ANALYSIS OF SOFTENED WATER

GRAINS PER U. S. GALLON

	Raw.	September 10, 1909.	September 30, 1909.	October 10, 1909.	May 25, 1910.
CaO, ...	8.220	.758	1.014	1.107	.656
MgO,.	1.574	.991	.548	.932	.845

The cost of softening this water is 1.2 cents per thousand gallons.

We present the analysis of a very hard water applied to domestic use:

Table V

ANALYSIS OF A VERY HARD WATER

(Altitude 420 feet.)

	Grains per Gallon.
Calcium carbonate	12.86
Magnesium carbonate	0.00
Calcium sulphate	96.90
Magnesium sulphate	38.60

The cost of softening this water is nineteen cents per thousand gallons.

Water containing above ten grains of calcium and magnesium carbonates and forty grains of gypsum is about the limit for the lime soda softening process when the water is used in boilers.

Four wells approximately sixty feet in depth sunk in alluvial drift at Cortland, N. Y., altitude at surface 1100 feet gave water of the following composition:

Table VI

ANALYSIS OF WELL WATER AT CORTLAND, N. Y.

	Grains per U. S. Gallon.			
Calcium carbonate	6.12	7.67	8.16	8.66
Magnesium carbonate	1.86	2.00	1.69	2.73
Calcium sulphate	2.72	.92	1.92	.84
Magnesium sulphate	.00	....	....	....
Silica	.29	.25	.24	.25
Sodium chloride	....	....	.40	.45
Oxides of iron and aluminum	.13	....	....	....
Magnesium chloride	....	.475	.62	....
Total solids	11.15	14.40	18.08	13.

These wells are to be found within an area of a square mile; are used for manufacturing purposes and give good satisfaction. Boiler compounds are used with each. The analyses given in Table VII shows variation in quality of water at various depths.

Table VII

ANALYSIS OF WATER FROM DRIVEN WELL, TRUXTON VALLEY, CORTLAND CO., N. Y., ALLUVIAL DRIFT

Surface Altitude about 1130 Feet.

	Grains per Gallon.		
	10 Feet.	20 Feet.	40 Feet.
Chlorine	.105	.594	.524
Free ammonia	.000	000	.000
Albuminoid ammonia	.001	000	.000
Nitrates	.070	.074	.065
Nitrites	.000	.000	.000
Oxygen absorbed	.012	.012	.005
Calcium oxide	3.906	3.789	3.672
Magnesium oxide	1.166	.816	1.008
Sulphur trioxide	1.240	1.000	1.026
Total solids, 212° F.	10.260	9.211	9.328

Table VIII shows the variation in composition of water in the same locality.

Table VIII

ANALYSES OF WELL WATER AT ONEIDA, N. Y.

Water from wells approximately 100 feet deep.

	Altitude Surface, Feet.		
	A	B	C
Calcium carbonate	8.30	7.39	18.00
Calcium sulphate	7.93	.....	1.70
Magnesium carbonate	0.00	2.42	.....
Magnesium sulphate	3.19	.....	13.60
Magnesium chloride	6.82	2.21	3.56
Silica	.07	.08	.....
Oxides of iron and aluminum	.03	.01	.....
Sodium chloride	23.95	12.65	.40

A is used with soda ash. B is used directly in steam boilers with little scale. C is used with difficulty in steam boilers.

Table IX

ANALYSIS OF WATER FROM WELLS IN ALBANY—BUFFALO BELT

Grains per U. S. Gallon

	Altitude.	Probable Strata.	Depth. Feet.	$CaCO_3$.	$CaSO_4$.	$CaCl_2$.	$MgCO_3$.	$MgSO_4$.	$MgCl_2$.	Na_2SO_4.	NaCl.	SiO_2.	Fe_2O_3. Al_2O_3.	Hardness.	N_2O_5.
Albany	6	Hudson shale	150	16.320	1.500	.000	.303	11.600	.000	2.017	2.506				
Schenectady, Rotterdam Supply	246	Drift	35	5.830	.910	.000	1.260	.758	.000	.000	.583				
Canajoharie	306	Unknown	530	11.450	4.450	.000	.368	1.749	1.539	.000	10.365	-----	----	----	.089
Canajoharie	306	Unknown	130	14.680	.000	000	.000	4.722	.000	.728	4.006				
Ilion	392	Laurentian rock	1135	6.867	.000	.000	2.010	1.750	.000	.000	.050	.30	.200		
Utica	407	Utica shale and lime-stone	1270	9.370	.770	27.43	.930	.000	19.400	.000	295.000	.60	.540		
Utica	407	Drift	100	1.950	.000	.000	.000	.000	.000	.000	86.370	1.560	.900		
Oneida	403	Shale	100	7.390	.000	.000	2.420	.000	2.210	.000	12.65	.080	.010		
Syracuse	480	Gypseous shale	60	14.220	29.150	.000	.000	13.600	.000	.000	1.340				
Syracuse	415	Gypseous shale	60	16.960	87.460	.000	.000	15.550	.000	.000	1.250				
Syracuse	500	Gypseous shale	220	12.860	96.900	.000	.000	38.600	.000	.000	4.460				
Syracuse	440	Gypseous shale	250	12.800	96.190	.000	.410	18.010	.000	.000	4.950				
Jordan	395	Gypseous shale	1350	12.880	95.720	.000	1.000	15.330	.000	.000	4.660				
Rochester	513	Niagara limestone	25	40.285	6.821	------	1.107	24.544	12.184	-----	15.741	-----	----	21	
Medina	543	"Red Horse"	42	11.420	12.300	.000	1.630	12.300	.000	4.160	2.910				
Buffalo	583	Unknown	430	5.830	59.290	.000	.000	4.540	.000	.000	62.140				

Cost of Drilling Wells. In this particular we have the following from a prominent well-drilling concern:

"Replying to your favor of the 18th inst., we would say that so much depends upon local conditions that it is impossible to make estimates off-hand that will be more than approximate cost of drilling wells. The character of the formation, the size and depth of the hole, skill of operators, cost of labor and fuel, etc., all enter into the problem. Current contract prices for this work vary from seventy-five cents to $20 per foot. A fair average for shallow wells (up to say 400 feet deep) including casing when needed would perhaps be about $1.50 per foot for a hole not exceeding six inches diameter. Up to say 2000 feet deep and an eight inch hole the cost would probably run from $2 to $5 per foot. Above 2000 feet from $5 up. These prices contemplate average conditions. When exceptionally hard rock or deep pockets of quick sand are to be entered, the expense would be increased and the rapidity of the work would be decreased. As an illustration of the effect of varying conditions, we have records of six inches per hour in hard granite and 20 feet per hour in soft formations, made by the same machine and both considered satisfactory progress under the conditions confronted.

Cost of Drilling Wells. *Ithaca N. Y.* To 500 feet, $2 to $3 per foot, not including casing. Six to eight inches in diameter ordinary rock $3 to $5 per foot to 2000 feet.

Dakota. Two inch wells 285 feet deep, 42 cents per foot; six inch wells $5 to $6 to 1000 feet.

Vermont. $1 to $5 per foot.

Los Angeles. Fifty cents to 100 feet, 25 cents extra each succeeding 50 feet, casing extra.

Galveston, Texas. Cost, single well, $12,000.

Cost of Pumping Water. To raise 1,000,000 gallons of water 50 feet in ten hours, theoretically, requires 21.06 H.P.

If a steam pump were to run at an efficiency of 75 per cent, 28.08 H.P. would be required; at 60 per cent efficiency 35.10 H.P.

Using a belt-driven pump with a liberal allowance for friction, 38 H.P. would be needed.

If belt-driven from a non-condensing engine, run 10 hours per day, 312 days per year, the cost, without depreciation, would total approximately $1900 or $6 a day. If driven by a cut-off

condensing engine, the cost would be about one-half as much, $950 or $3 per day.

A 1000 H.P. plant running condensing requires at least 500 H.P. boiler capacity. If the boiler water is pumped 50 feet against gravity and again against a boiler pressure of 125 pounds, the total height amounts to 338 feet. Using a total, including blow-off, of four gallons per boiler H.P. per hour, the day's run of 10 hours requires 166,800 pounds of water. This requires theoretically 2.84 H.P. pumping capacity. Allowing an efficiency of from 60 to 75 per cent, a four H.P. pump would handle this under medium load and one double the capacity would be required for peak loads. To pump the condensing water for this plant from a well 50 feet deep would require 14–17 commercial H.P., allowing 25 gallons of cooling water for each gallon of water condensed.

Failures. The list of deep and expensive wells that yield little or no water is a long one. As instances, we mention the following:

Northampton, Mass., 8 in. well	3700	ft. deep
New York Mills, N. Y.	1900	"
Utica, N. Y., driven 1000 feet to quartz rock	1270	"

TABLE X

YIELD OF CERTAIN WELLS

Location.	Depth. Feet.	Yield. Gall. per Day.
Galveston	800	250,000
Fort Worth, Texas	1000	300,000
Buffalo	450	216,000
Hartford, Conn., av., 34 wells	80	each 14,400
Holyoke, Mass.	720	64,800
Ithaca, N. Y.	287	400,000
Rochester, N. Y., Gale Well	140	300,000
Pawtucket, R. I.	.....	350,000
Leominster, Mass.	.....	159,000
Portland, Me.	.....	100,800
Albion, N. Y., 7 wells	.....	324,000
Warwick, N. Y.	.....	145,000

LOSS IN COAL DUE TO STORAGE

By A. BEMENT

Read at the Niagara Falls Meeting, June 24, 1910

In recent years, the threatened interruption of coal production brought about by the cessation of mining pending wage settlement between operators and miners, formally designated as a strike, has made it necessary, particularly for large users of coal, to carry fuel in storage for use during the time that mines may be inactive. Thus the question of its deterioration under such conditions is one of interest.

During the last few years the author has made investigation concerning the deterioration of certain Illinois coal, for Mr. W. L. Abbott of Chicago. The first work consisted in experiments to ascertain the loss in heating power caused by storage. While that work was largely of a preliminary nature, the loss in heat value appeared to be much smaller than popularly supposed. As it is necessary to test the coal in its original condition and then again after storage, such investigations extend over long periods of time. The experiments in question covered a period of some three years, with fuel which had been exposed in outdoor storage in each case for one year. Upon the completion of the first year's work it was felt that the matter of loss or gain in the weight of fuel, or in other words, its quantity, as well as heating value, was an important feature. To this end, during the second year, experiments were made to ascertain change in weight as well as in heating power, and while the work gave useful results, as well as serving to develop an accurate method of testing, the results were really of preliminary character. At this point, having the benefit of two years' experience, another series of tests were planned and carried to a very successful conclusion, giving results which the author believes to be especially accurate and which may be accepted with confidence.

The tests consisted of:

(*a*) Change in heating power.

(*b*) Change in weight of the coal.

(*c*) Tendency to disintegrate by slaking.

The greatest difficulty was in accurately determining the change in weight. As the sample must be exposed to the weather under representative conditions, it was subjected to the possibility of an increase in quantity, due to dust and dirt which might be carried into it by the wind. On the other hand, it was subject to loss by small particles of coal being washed away by water from rainfalls passing through it, or carried away by wind. To guard against these contingencies, coal containing no dust was selected, placed in a box large enough to hold a 400-pound sample and covered with cheesecloth to catch dirt. Drainage from the box was so arranged that the water would flow at a low velocity through a trough, in which dams or riffles were placed to catch any dust that might be carried out with the water. In preparing the sample of coal to be tested a size was selected which in preparation passed over a screen having $\frac{1}{4}''$ round perforations and through one with $\frac{5}{8}''$ perforations. This sample was taken then in an air-dry state and carefully rescreened over a screen having $\frac{3}{8}''$ perforations. This rescreening eliminated all of the small stuff and left a clean uniform size of coal, which was then sampled and analyzed, the remainder being weighed and placed in storage in the box. When the coal was taken out of storage its weight was taken, after which it was sampled and again analyzed. Heating power determinations were made with a Mahler calorimeter at the same time the analyses were made. In determining change of weight, calculations were based on the same moisture content as that present in the coal in the initial state. This was because coal does increase and decrease in moisture content independent of any change that may affect the ash content or that of the coal proper. Thus the final weight of the dry coal referred to its initial weight gave the change due to weathering.

Illinois coal production is practically all from four seams, but the Illinois coal used in Chicago for steam production is nearly all from two of these seams, which are Nos. 5 and 6. In fact these two seams produce 75 per cent of the entire output of the State. Seam No. 6 is by far the larger producer of the two. Until recently, however, that portion of seam No. 6 lying east of

the city of Duquoin in Perry County, which is extensively operated in Williamson, Franklin and Perry Counties, has been known as No. 7. One of the things that gave reason for belief that it was a different seam from No. 6, is that the quality of its coal is better than that in the remainder of the seam to the west and north. Thus the two general fields in this seam have a different character.

Seam No. 5, in the vicinity of Springfield, also produces a considerable amount of coal finding a market in Chicago. While the principal fuel supply is from seam No. 6, it was felt desirable to test also the behavior of seam No. 5, as to change in heating power and its tendency to disintegrate by slaking down to smaller size. The reason why no test for change in weight was made, was that at the time it was felt that the data from seam No. 6 would be sufficient. Therefore, a sample of mine run coal corresponding to the others in amount was put in storage for that purpose. It was analyzed and heating power determinations made upon it, the same as with the two samples from seam No. 6.

The average composition of seams in the three fields tested is given in tables Nos. 1 and 2, which serve to show the character of the coal.

TABLE NO. 1

PROXIMATE COMPOSITION OF COAL SEAMS

	No. 5. Springfield.	No. 6. Central.	No. 6. Southern.
Moist Coal:			
Moisture	12.66	14.38	9.65
Ash	10.75	10.01	10.99
Volatile matter	37.23	36.23	31.55
Fixed carbon	39.36	39.38	47.81
Heating power in B.T.U.	10,990	10,774	11,178
Dry coal:			
Ash	12.31	11.69	12.16
Volatile matter	42.63	42.32	34.92
Fixed carbon	45.06	45.99	52.92
Heating power in B.T.U.	12,583	12,584	12,803
Pure coal:			
Volatile matter	48.61	47.92	39.75
Fixed carbon	51.39	52.08	60.25
Heating power in B.T.U.	14,350	14,250	14,575

TABLE NO. 2

ULTIMATE COMPOSITION OF COAL SEAMS, PURE COAL BASIS

	No. 5. Springfield.	No. 6. Central.	No. 6. Southern.
Carbon	77.23	75.74	81.63
Hydrogen, available	4.02	3.63	4.02
Sulphur	4.45	5.24	2.14
Nitrogen	1.60	1.51	1.73
Water of combination	12.70	13.88	10.48
Total	100.00	100.00	100.00

Table No. 3 gives the results of the tests showing change of weight and heating power with the exception that, as no determination was made of the change of weight with the sample from seam No. 5, the figure used to represent this loss was derived upon an assumed basis to be described later.

TABLE NO. 3

CHANGE DUE TO EXPOSURE IN AIR

Coal Seams.	Change in Per Cent.		
	Heating Power.	Weight.	Total.
5 Springfield	−0.93	−1.15	−2.08
6 Central	−1.85	−2.29	−4.14
6 Southern	−0.38	+0.11	−0.27

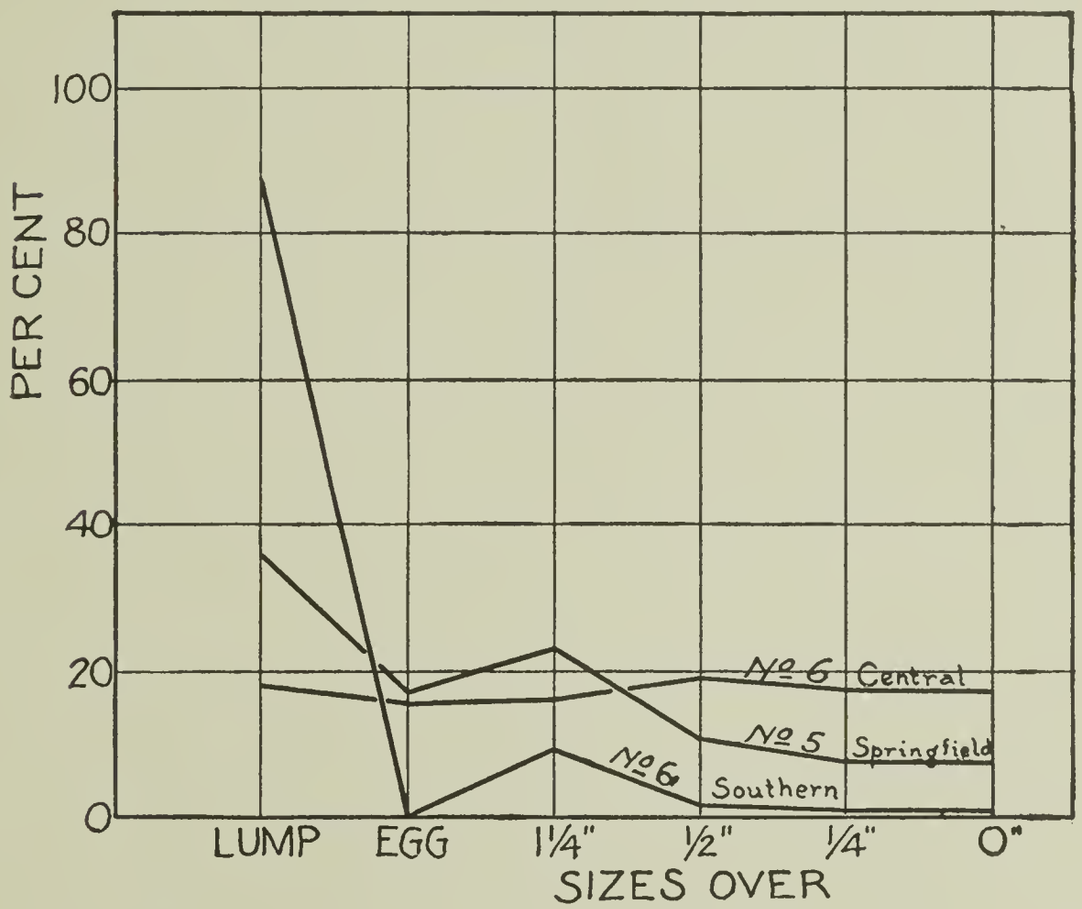
The question of change in coal stored under water was also a matter which presented itself, and tests conforming to those above described were made upon samples stored under water for one year in glass jars, which sat upon a shelf in the laboratory. The result of these tests is presented in table No. 4.

TABLE NO. 4

CHANGE OCCURRING UNDER WATER

Coal Seams.	Change in Per Cent.		
	Heating Power.	Weight.	Total.
6 Central	−0.44	−0.35	−0.79
6 Southern	+0.02	−0.81	−0.73

In Illinois, as well as in the remainder of the Eastern Region of the Interior Coal Province, the product is lump, mine run, egg, nut and screenings. When storage was first attempted, in many cases screenings were stored. It was found, however, impracticable to handle such fuel on account of its catching fire, sometimes very soon after being put in the pile, and it was also found that mine run would store with very much less danger of



Disposition of lump coal to slack down to smaller size. Exposure of one year. Seams Nos. 5 and 6 of Illinois. Original samples 100 per cent lump, which in one year's outdoor storage broke down to sizes as shown.

fire. With this larger coal, however, it was also discovered that there was a disposition for it to disintegrate and slake down into smaller sizes. Thus the best practice has been to place egg coal in storage, as it appears to show the least tendency to deteriorate by slaking and is free from tendency to spontaneous combustion if not disturbed until used.

The disposition of coal from the three fields in question to disintegrate by slaking down into smaller size was considered a matter of sufficient importance to justify careful tests to deter-

mine this feature. Therefore a considerable number of average lumps of coal from each of the fields were placed in outdoor storage for one year, the weight being taken at the start. These lumps were so placed that the portion scaling off remained associated with the original lump. At the end of the year that portion of the original lumps remaining intact was weighed, and the total weight referred to the original weight gave the percentage of the original lump still remaining intact. The remaining portion was separated into sizes each of which was also weighed, thus showing to what extent the sample remained as lump and what sized pieces the disintegrated portion was disposed to take. The results of these tests are illustrated in the accompanying diagram, which shows that coal from seam No. 6 Southern retained its integrity as lump to the extent of 87.84 per cent, while No. 5 retained it to the extent of 35.49 per cent and No. 6 Central only to an extent of 18.36 per cent.

After the work was completed, it appeared desirable to have, as above mentioned, some figure representing a value for change in weight for seam No. 5. Therefore, the figure used in the table was determined by assuming that the tendency for loss in the weight would be in the same ratio as the tendency to deteriorate by slaking, thus the figure representing a weight loss of 1.15 per cent was arrived at.

NITRIC ACID

A Few Notes and Remarks Relating to its Manufacture

By SCHUYLER FRAZIER

Read at the Niagara Falls Meeting, June 24, 1910

No attempt is made herein to explain the methods of manufacturing nitric acid according to present practice. The most modern methods are best understood by men at present actively employing them.

Engineers so situated will be competent to present the art in its recent development and to compare results with those obtained by the older methods. For one, I should be much interested in information produced regarding the real detail of what has been accomplished within the last few years. Some of us remember the time when considerable nitric acid was prepared by means of cylindrical retorts in which the charge was so proportioned that neutral sodium sulphate was the by-product. When the nitric acid had been driven over, the retort was allowed to cool and the iron head removed. The hard mass of sodium sulphate was then laboriously mined by use of chisel bars and sledge hammer. Retorts were frequently renewed because of blistering and cracking. Later a cylindrical retort with brick heads was used, but the proportions of the charge regulated so as to produce sodium bisulphate, which was tapped from the cylinder in a molten condition. This method was a decided improvement in saving of time and labor in discharging the residue, also in increasing the life of the retort. These retorts have been used of 5 feet diameter and 9 feet length, made of cast-iron. At one time it was noticed that the greatest deterioration of the metal of the cylinders occurred near the ends at the top. (The position of cylinders was horizontal and it was enclosed in brickwork excepting at the ends.) This damage was later largely reduced by closing the openings, viz., discharge

door and nitric vapor outlet, immediately upon discharge of residue. Apparently the entrance of cool damp air caused the local action mentioned.

Originally the nitric acid condenser consisted of about a dozen 35-gallon stoneware receivers located on a horizontal wooden table at about 30 inches elevation above the floor. The nitric acid vapor was conducted through these receivers in series by means

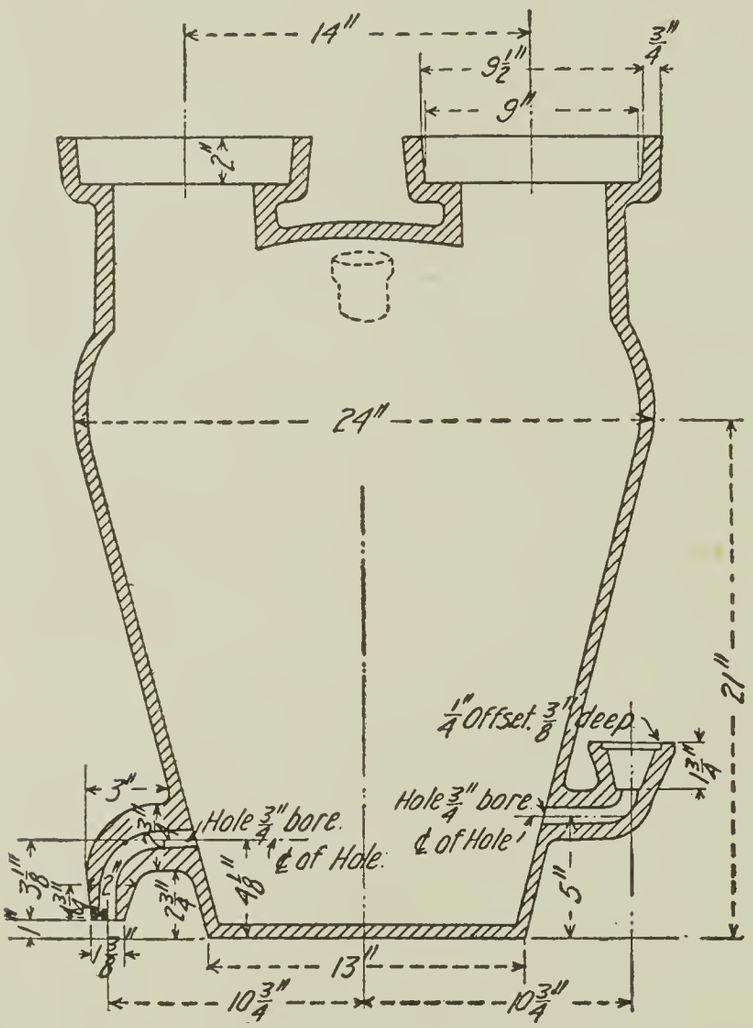


FIG. 1.—Receiver, Made of Chemical Stoneware.

of connecting pipes of rather limited opening. This condition together with insufficient cooling surface necessarily limited the rate of distillation. No provision existed in most cases for recovering the uncondensed vapors. The luting of connections was very poor and a nitric acid plant was chiefly remarkable for its highly colored atmosphere. The nitric acid had to be siphoned out of each individual receiver and there was a remarkable variation in strength and composition of acid so obtained from the various receivers.

For years nitric acid was heated in glass retorts to remove the chlorine and lower oxides of nitrogen; later for certain uses this was done more economically by warming the acid in large stoneware jars set in water-baths and blowing compressed air

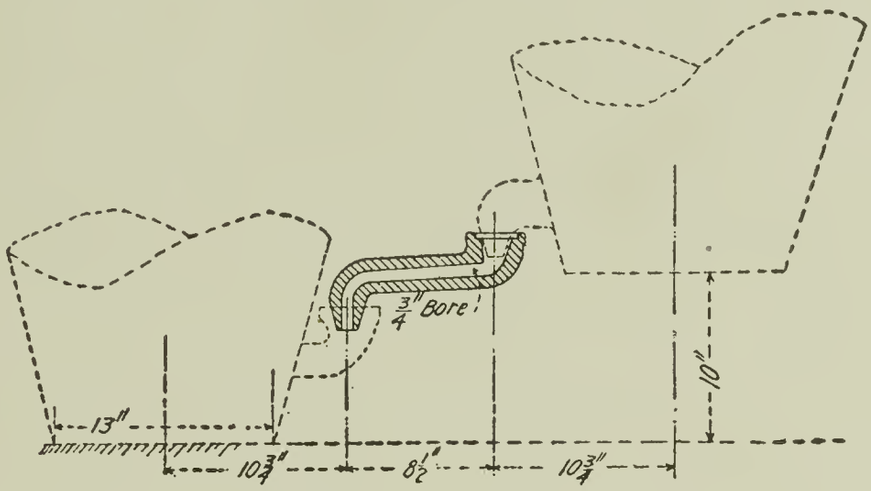


FIG. 2.—Acid Tube, or Connecting Pipe.

through the acid. The latter method was satisfactory for strengths of 42° Bé. and upward. About fifteen years ago the writer developed a form of nitric acid condenser shown in Figs. 1, 2, 3, 4 and about eight years ago the retort shown in Fig. 5.* The condenser

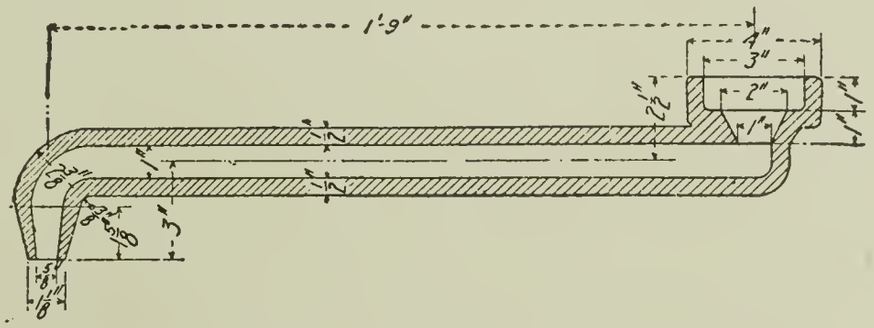


FIG. 3.—Long Acid Tube, to carry acid into receiver near retort.

in question provided a remedy for the several objections to the older form of condensing receivers indicated above.

1. The addition of standpipes provided much more surface for natural cooling.

2. The arrangement of receivers in steps with outflow pipes for acid did away with the necessity for siphoning acid out of the receiver.

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* For fuller description of the retort and condenser, see *The Chemical Engineer*, vol. x, p. 160.

3. Bringing the acid to one point of delivery eliminated largely the great variation in qualities.

4. Flowing the acid from cooler into warmer portions of the condenser and finally through a bowl set within the receiver closest to the retort where the acid is exposed to hot vapor while agitated by a small jet of compressed air, resulted in very good purification.

The pot-shaped retort was adopted as a convenient form which could be so built in the fireplace that the fire gases might warm every part and thus increase the life of the retort. Ease of charging and discharging were considerations also. A later improvement included protecting the cover by an interior lining of brickwork.

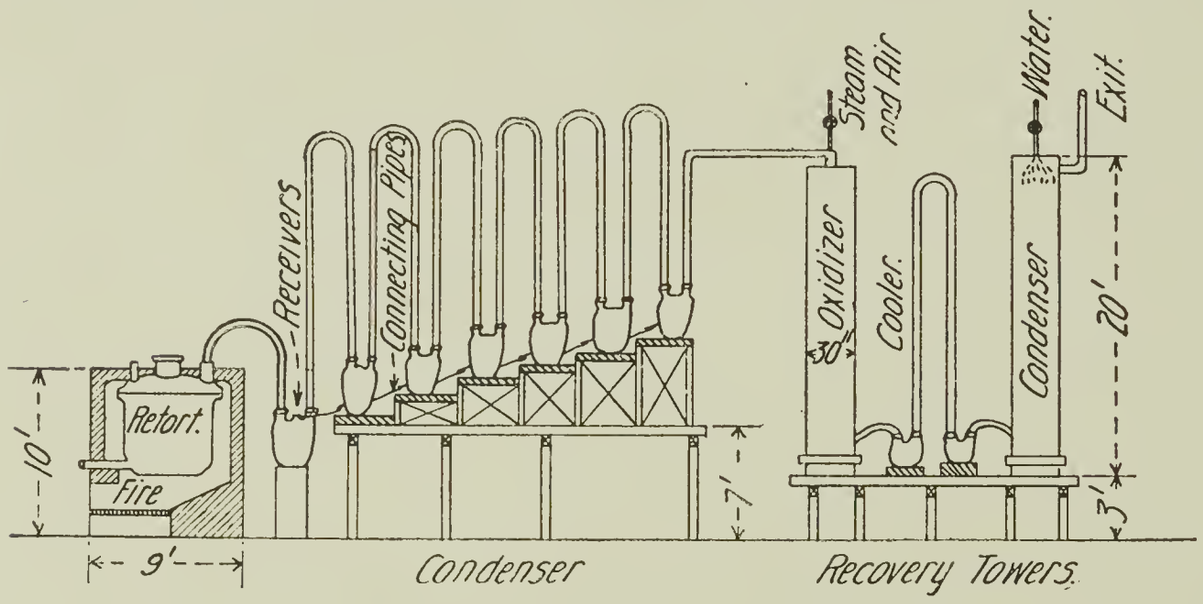


FIG. 4.—Complete Nitric Acid Plant.

This form of retort proved more satisfactory in respect of operating and repair costs than the cylindrical type.

A total yield of nitric acid equivalent to 68 pounds of 94 per cent HNO_3 from 100 pounds of 96½ per cent nitrate soda was considered very good as a monthly average product from the types of plant just mentioned which of course was some improvement over yields recorded say twenty years ago. When operating retorts and condensers of ordinary forms it is found that the rate of distillation must be kept within certain limits in order to secure the largest yield of acid. A desire to expedite operations, to improve quality and quantity of product has caused the invention of numerous designs in the way of apparatus for manufacturing nitric acid, many of which, while very ingenious, have proved

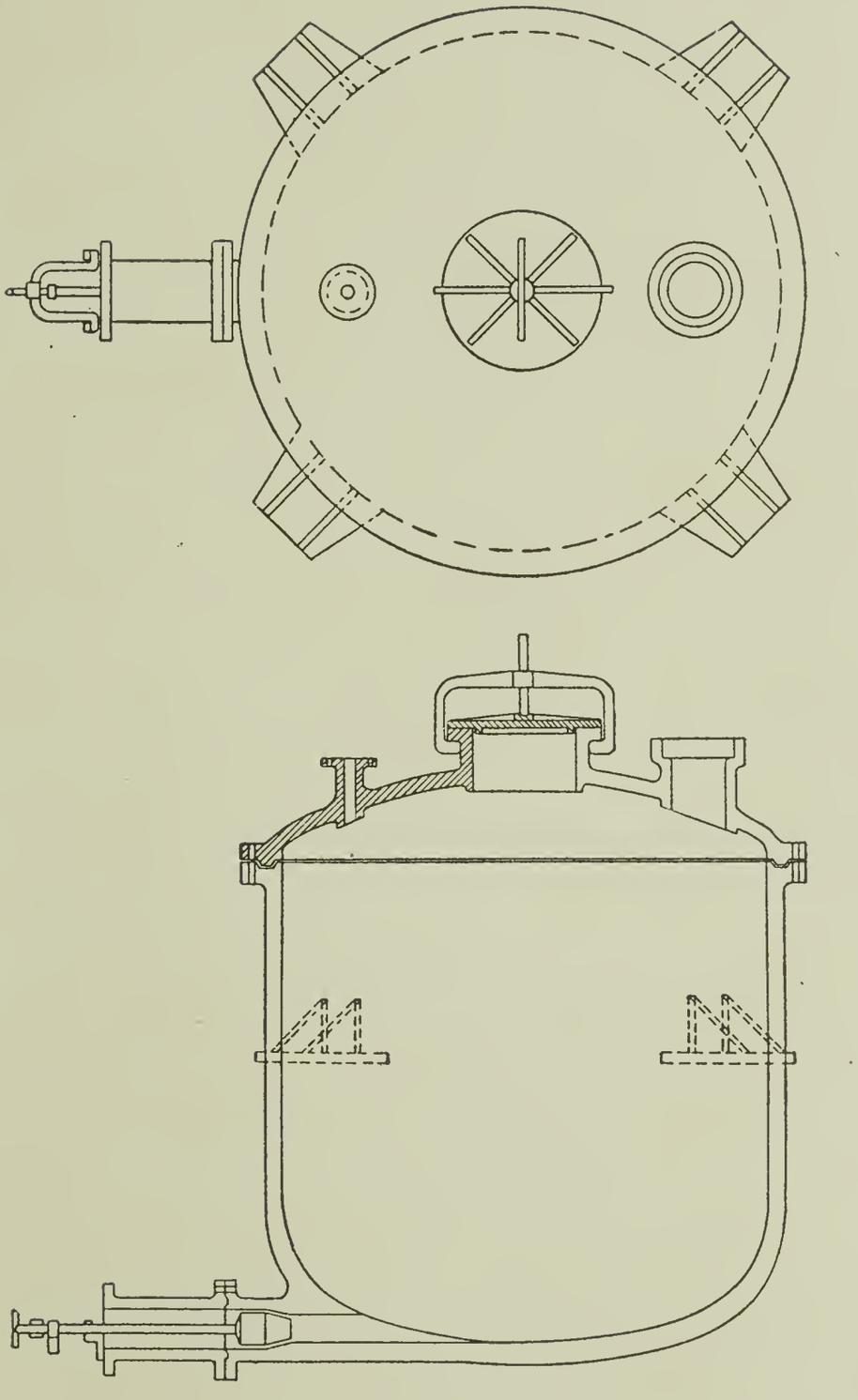


FIG. 5.—Cast-iron Retort, for production of nitric acid from nitrate of soda.

expensive to the firm attempting to employ them. No doubt our friends who may take up the subject of nitric acid further will decide that it will be profitable to omit history of such attempts and to elaborate the newer and really successful plants of to-day.

Below are given a few selections taken at random from a mass of data, obtained during a long period of operating cylindrical retorts, giving comparative temperatures of retort and qualities of product. These figures indicate only the working of the retort—not the condenser results.

RECORD OF EXPERIMENTAL NITRIC ACID DISTILLATION FROM 2000 POUNDS NITRATE OF SODA AND 2280 POUNDS SULPHURIC ACID 97 PER CENT, DONE IN CAST-IRON CYLINDER 9 FT. LONG, 5 FT. DIAMETER.

Time.	Temperature.		Gravity.	Available HNO_3	N_2O_5	Comparative Volume of Nitric Condensed. Per Hour.
	A	*B*				
6 P. M.	170	168	.....	.....	.....	.....
7	190	196	52.4	95.05	3.77	1
8	207	205	52.3	95.76	3.80	1
9	217	215	52.2	96.76	3.72	1½
10	234	230	52.3	96.74	3.76	2
11	246	241	51.4	98.14	2.56	2½
12	248	250	50.6	97.49	1.74	2¼
1 A. M.	253	257	49.8	97.02	1.12	3½
2	258	264	49.0	94.12	0.91	2½
3	264	272	48.5	91.44	0.89	3
4	268	280	48.1	89.50	0.77	2
5 *	273	295	48.5	87.03	1.80	1½
6 †	290	310	47.1	80.40	2.32	1
9	.....	360	25.	30.70	0.48	.....

* Cut-off point for 94 per cent. HNO_3 at temp. A. 280° F.
† Cut-off point for 93 per cent. HNO_3 at temp. B. 310° F.

Thermometer *A* was inserted in hole drilled in front of cylinder at bottom of same, hole filled with mercury.

Thermometer *B* was inserted through brick head at rear and top of cylinder. The temperature is indicated in degrees Fahrenheit.

N. B. The nitrate soda used was ordinary damp 96½ per cent commercial article.

RECORD OF TEMPERATURES TAKEN BY THREE THERMOMETERS PLACED RESPECTIVELY ON FRONT OF CYLINDER IN HOLE DRILLED IN CAST-IRON, ON BACK INSERTED THROUGH BRICK HEAD INTO CHARGE AT BOTTOM AND ON TOP THROUGH BRICK HEAD ALSO, INTO THE GAS.

Cylinder No. 14, fired up at 5 P.M.

Time.	Front at Bottom. *A.* Deg. F.	Back at Bottom. *B.* Deg. F.	Back at Top. *C.* Deg. F.
5 P. M.	142	160	195 before firing
5.30 "	144	160	200
6 "	150	160	205
6 "	160	170	210
8 "	170	180	220
9 "	180	200	230
10 "	190	210	235
11 "	200	220	240
12 "	210	230	245
1 A. M.	215	235	248
2 "	215	235	250
3 "	220	236	260
4 "	230	237	280
5 "	240	238	290
6 "	250	240	300
9 "	274	235	325

RECORD OF CYLINDER NO. 3 FIRED AT 3 P.M., AND PRODUCT OF DISTILLATION SAMPLED EVERY HOUR, THE NITRIC BEING CONDENSED BY GLASS TUBES THROUGH WATER-JACKET, THE THERMOMETER BEING PLACED IN BACK HEAD OF CYLINDER THROUGH BRICK NEAR TOP.

Time.	Temp. Deg. F.	Acid. °B.	Avail. HNO_3.	N_2O_3.
3 P.M.	fired up slowly	.....	.....	.....
6	163	.....	no distillation at	this temp.
7	195	52.1	97.40	2.96
8	208	52.	97.90	3.20
9	220	51.8	.....	3.19
10	234	51.6	96.11	3.20
11	245	50.4	.....	2.07
12	254	49.1	.....	0.84
1 A.M.	262	48.7	93.23	0.76
2	270	47.8	.....	0.41
3	276	47.6	88.76	0.52
5	283	48.	.....	0.84
5	295	48.	87.65	1.24
6	305	46.8	87.65	1.34

Discussion

Dr. Grosvenor:

I am very sorry that the author is not here to discuss the paper ("Nitric and Mixed Acids"). One of the systems which might be compared with the one we have been viewing is the Skoylund system. It has been found to give very excellent results. The system is covered by patents, and not generally available, but as a matter of chemical engineering, the process is extremely interesting, and one that I have always admired very much. A series of from two to four retorts is connected with a single tower of suitable proportions and filling, and the retorts are operated in succession—one is charged in the morning, and the next in the middle of the afternoon, and the next in the evening, etc. They work along behind each other in such a way as to give a steady supply of hot mixed nitric acid and lower oxides at the bottom of the tower. At the top of the tower is a reflex cooler, connected to a series of final oxidation towers, and where a moderate strength of nitric acid is desired, the product of the oxidation tower is pumped back up and run down into the condensation system. The average of all acid obtained from such a plant will be about 87–88 per cent, which is ample for making high-grade mixed acid, where strong oleum is available. As in Mr. Frazier's system, no purification of the acid after preparation is needed. With proper regulation the hot gases are made to purify the acid both from lower oxides and chlorine, and a substantially water-white acid, with approximately 0.1 to 0.12 per cent lower oxides is obtained from the bottom of the tower in a pretty steady supply, and of ample purity for the very best mixed acid. From the engineering point of view this seems to cut out approximately one-third of the cost of installation and about 25 per cent of the labor and repair costs. It is the most satisfactory nitric acid process in simplicity and general efficiency that I happen to have seen in operation anywhere. Most of us are acquainted with the Vallentine process in operation at the Eastman Kodak Plant. It is a vacuum process, designed to reduce the temperature of operation and the formation of lower oxides. It is unfortunate that the author of the paper could not be here for comparison of some of these points.

PLANT LAYOUT

By W. M. GROSVENOR

Read at Niagara Falls Meeting, June 24, 1910

It is with great hesitation that I approach this subject, and especially before a body of men every one of whom is peculiarly fitted by occupation and experience to speak upon it authoritatively. Nor is there the justification that the spirit moves me. On the contrary, it whispers "Wait 15 or 20 years until you know something about it." With no expectation, therefore, of directly adding to our general fund of knowledge, but rather in the hope of starting discussion of great value to us all, are a few phases of the subject presented. The discussion of this topic and of the detailed subjects branching from the stem is one of the essential objects of the Institute; and the final results, our magnum opus, the great work in which we hope to present "Chemical Technology by the American Institute of Chemical Engineers," demands that we begin the organization and the presentation of the experience with which our elders are so richly endowed. Accept this as an apology for a hesitating entry upon a subject too large for the grasp of any one man.

The elements of the alchemist are the elements of our problem. Earth, air, fire and water. The intelligent layout of any manufacturing plant demands preliminary consideration of these elements and of one other with which the alchemist had but the remotest acquaintance, transportation.

In certain industries one or other of these five is pre-eminent, but careful consideration of every single one is essential.

By "air" we understand the presence of an atmosphere which is not too much contaminated for the purpose in hand and which we ourselves shall be free to contaminate—at least to that extent justified by our own profit and loss. The earth must support our structures, receive certain of our wastes, to its surface we must

adapt the arrangement of our plant (or modify its contour to suit our needs) and from it many industries draw their raw material. The air must animate our workmen, must carry away our dust and fumes where they shall not be objectionable; it enters into a multitude of our reactions, must dry our materials, and above all, must not contaminate our products.

Prometheus may be regarded as the father of manufacture. Fire is essential to the fabrication of almost every material, and is essential in one form or another to the generation of that horse power which so far transcends the capacity of human effort and makes modern industry possible.

Water, receiving much of our waste, checking the drunken riot of Prometheus which so often lays waste our industrial plants, is needed in large quantities for the economic generation of our power by whatever means, and is required for cooling and recovery of our products. Many industries are so subtly dependent on the peculiarities of available water supply that all other industrial considerations become secondary.

And finally, transportation by rail or water, preferably both, makes possible that which we need and makes valuable the fruit of our effort.

Disregarding for the present all considerations of plant location or layout resulting from dependence upon the earth for raw material, let us consider its surface configuration. Consideration of freight rates on raw materials and on finished products as against coal prices, selling expenses, proposed capacity and market, should first determine the general location of the plant, within the district of consumption or elsewhere. Few strictly chemical plants or plants producing high-priced products considered topography of possible locations with a view to operating economy. The value of such consideration is well recognized in cement plants, coal breakers, stamp mills and some of the larger industries. But Reckless Waste which is so often said to characterize manufacturing in this country seems often to forget that a dollar is a dollar whether it be saved in the handling of a thousand tons of coal or the materials for 300 pounds of saccharin. For some industries level sites are desirable, but the entire layout of the plant having both rail and water facilities should be based on the gradient of the bank between the water on one side and the railroad on the other. At least two spurs (or place for the second,

etc.) should be provided. If a steep gradient is selected one spur should be between the railroad and the upper side of the plant, the other between the lower side of the plant and the water. If the level site is chosen the spurs may well meet the water at right angles, fanning away from the main track (generally about parallel with the water) in a series of curves. Sidings are desirable, but back spurs from a siding are very objectionable. Before the site is finally purchased, it may be necessary to study the railroads and navigable waters for miles and several possible locations may be roughly profiled in order to select that best suited to the floor levels required by the apparatus to be installed. Not only must the necessary difference of level be considered, but the necessary horizontal width to accommodate buildings for secondary treatment, etc., for working up of by-products, for final treatment, for finished storage and shipping facilities. A much higher price per acre is sometimes entirely justified in order to secure the desired advantages in this direction. Also the purchase of several times the area that would apparently serve the purpose of the plant and could be obtained at the lower price, but with less satisfactory topography, may be entirely wise. Branches of work to be carried out should be carefully studied with a view to transportation of all material downward at proper gradients, for gravity feed whenever possible and for trucking. Under proper conditions one man with a truck can transport loads that in many plants would require one or even two horses. To this end considerable grading of roadways and the best paving may be justified. The loading of trucks can be facilitated by pushing or scooping from platform floors, and unloading arranged for by dumping directly into bins or hoppers. Liquids and gases should be the only things willingly moved up-hill. Thus " labor-saving machinery " in the ordinary sense can often and with profit be almost wholly eliminated and be it said here (as a result of perhaps more than ordinary experience with it) that the installation of conveying machinery is like a surgical operation, very helpful when necessary and properly performed, but far better avoided if possible.

The heaviest single tonnage in many plants is found to be coal. The boiler plant can generally be located just below the incoming siding, or a separate trestle.

One important question to be decided may be what disposal should be made of the unoccupied land. A study of prevalent

winds generally shows that the plant can be located advantageously leaving such portion of the property to windward. And the first buildings constructed should then be a few workmen's houses, one of which can be immediately used for the construction office, draughting room, superintendent's quarters, storage of valuable materials and a couple of minor offices for the contractor or foremen. The importance of providing proper storage and working facilities during the construction period cannot be overemphasized. In one plant estimated to cost about $375,000, where such provision was not made and the office located at some distance, it was found that nearly $10,000 worth of materials purchased for the construction could not be discovered in the finished plant, and nearly as much more was unearthed in various out-of-the-way places after the plant started. The book value of construction ran up to nearly $500,000, and a good deal of the material discovered in the final clean-up was recollected to have been lost and replaced by extra orders with their consequent delay. Castings, valves, and even smaller rolls of sheet lead were revealed by the spring thaw and uncovered in clearing away piles of rubbish. An outside consultant called in to supervise the work demanded first, last, and all the time until he got it, a commodious storehouse adjoining the plant, and the inventory of that storehouse exceeded materials purchased for it by nearly $10,000.

It will generally be found that the purchase of a little "waste land" permits, by careful grading, the bringing together of the two sidings at their inner ends, making it possible to take the cars received after they were emptied around onto the shipping track. Provision should always be made for the later expansion of the plant parallel to the sidings of all storage and operation buildings in both directions from the power plant, so that the capacity of the plant may be increased four-fold without interfering in any way with the system of operating or handling materials. The work to be carried out divides itself into classes more or less interdependent and the arrangement of these buildings for convenient handling of material without interfering with expansion or extending too greatly the steam and power transmission, calls for exhaustive study. Various rough plans of the works should be studied over with the working foremen and the superintendent to make possible the more concrete view of these considerations.

The cost of coal in most cases is a considerable factor. The

amount of steam required for various operations calls for careful consideration, and its exhaust value for heating purposes, requires balancing against power demands. Branches of the work demanding power alone may be segregated and possibly made entirely independent of the general steam plan by providing this branch of the work with its independent power plant and dividing the electric light and power installation between the two units so that either is capable of carrying the entire plant on minimum demand. The units should, however, adjoin one another. A definite scheme can be outlined for increasing workmen's houses, disposing of the excess power for lights, some exhaust for heating and gas for cooking in these houses at very profitable rates. Similar service to adjoining portions of small towns has been profitably carried out. Careful selection of the men permitted to occupy the houses is made possible by properly separating the buildings themselves, a slight improvement in the character of their construction, the addition of a few conveniences, etc. These selected men constitute the reserves, always available in case of emergency, and the right of vacating any house on 30 days' notice should be reserved to the company. In these ways the excess land is made a most profitable investment.

Unfortunately, the character of the soil does not always permit the absorption of some of the liquid wastes, as would often be most desirable. However, in some cases, a study of certain of the solid wastes has indicated that when mixed with part of the ashes from the boiler plant, they were capable of absorbing with the beneficial cementing action nearly all of the liquid waste, and arrangements could be made for concrete piling the water front some distance out, giving ample filling space for years. After passing through this filling the liquid waste does not appear to have any injurious effect on the river water. Before difficulty can arise on the question of sanitation, plans should be outlined for meeting any objection that may be raised in years to come by communities further down the stream.

The question of fire risk must be considered in the original layout of the plant, and while the character of manufacture may not preclude the use of cheap shed walls, at least one higher wall between each building and the next should be built of reinforced concrete with minimum openings and automatically released fire shutters and doors. Certain parts of the plant in which fire risk

seems considerable should be provided with automatic sprinklers, gravity fed if possible, from the upper level of the land, the reservoir for this may serve as the settling portion of the water-supply system for the steam plant and being sectionally divided to permit of cleaning. One point frequently overlooked in the original layout of the plant is proper roof drainage and sufficiently inclined water-ways to prevent flooding of passages and even of the first floors of buildings during heavy storms. An inclined site offers easy solutions of this difficulty, but the utmost ingenuity is sometimes required—and sometimes fails on flat sites.

Lack of proper water supply alone prevents location in some places which otherwise present great attractions. There may be a great deal of suspended matter in the river water, perhaps at certain seasons only, or organic matter may entirely unfit it for the purposes in mind. A small stream of assured volume, a mile or so away, however, may furnish an excellent supply of water for boiler purposes if an old settler owning land on both sides of the stream can be persuaded to sell his place with all rights or execute a long term lease at reasonable rental and a cash consideration. A little money spent on converting a portion of his cow pasture into a reservoir and on piping to the plant reservoir, would assure prior right to a water supply which could then be protected from interference. Condenser water, required in much larger volume, may generally be obtained from the navigable water and the piling arranged along the water front of the property (with a top inflow upstream and a bottom outlet downstream), provides a settling chamber from which even at the worst seasons fairly clear water can be obtained. If pure water is important, as in certain textile and plastic industries, artesian wells offer a most desirable solution of the problem, but should then be the first part of the plant completed and thoroughly tested, and these tests should be made more than mere analysis, should in fact be most thorough factory tests. One company temporarily lost its position of pre-eminence simply by neglecting to take every precaution as to the character of its water supply in locating a new plant.

In considering the preliminary elevation it is sometimes wise to locate the greater portion of the entrance siding on concrete piers, taking precaution for the preservation of ties and utilizing the space below the rails for storage of broken stone, sand and such

material as would not be injuriously affected by the weather. The considerable amount of grading sometimes incident to making these places more easily available, may gradually be accomplished to the advantage of the workmen's yards. The amount of excavation necessary for each of these houses can be considerably reduced by allowing the foundation to extend somewhat above the ground. General transportation facilities within the plant must be most carefully thought out. Only where the tonnage or volume of material to be handled is great, should automatic machinery be considered. One form of conveyor by no means sufficiently appreciated is the overhead trolley and grab-bucket. Repairs are extremely small, capacity is enormous and general utility for handling all sorts of materials is not to be overlooked. Provision can be made for dropping the grab-bucket and using the same traveler for handling other materials or using other specially designed travelers on the same rail. In the small plant properly designed trucks and roadways are of great value. A little ingenuity of design has enabled one man to handle 36 dry barrels from the cooper house to point of filling in the same time, and with little more effort than were formerly required to move two. Properly designed runways enabled two men to deliver 100 barrels an hour on demand. The universal force to which the engineer should look for the transportation of his materials is gravity. One interesting illustration of this idea properly applied is the plant of the Wood Products Company, in Buffalo. Many thousands of gallons of liquid are handled without pumping. Receiving is done on the first floor, distillation is generally done in the basement, condensation is done on the roof, grading on the intermediate floors, storage on the second floor, barreling on the first floor, and shipment again from the ground floor. If city water must be used, pumping for condensation need not be considered, but if condensation must be done by pumping water to the roofs, it may be far cheaper to pump condensed products and maintain condensers at or near the ground level. Modern developments of stoneware fans and pumps, automatic eggs, Pohle air-lifts, and similar devices make the questions attendant upon the handling of gases and liquids relatively easy of solution provided the general desirability of making one long lift if necessary and working back by gravity for the successive minor stages is kept in mind. Handling of solid materials, however, presents an almost infinite variety of prob-

lems. So far as I am aware, no general classification or systematic division of the subject has been attempted. None may be possible. It seems almost as though each case must be viewed as a case by itself in the light of experience to be gained only by attempt and failure, with the co-operation of those who have learned by failure. Numerous illustrations come to mind. One peculiar case is remembered in which the operation and maintenance cost of the conveyor was nearly double the apparent cost of labor required to do the work by hand, but in which nevertheless the conveyor was amply justified. Car wheels had to be moved from the foundry to the finishing and dressing shop across four railroad tracks from which the extended view was shut off in both directions by curves. The traffic was both freight and passengers, partly suburban, partly express. Accidents had led to the posting of four special signal men. In spite of this, the passage across the tracks had cost the company ten or fifteen thousand dollars damages and led to strained relations between them and the railroad. There were somewhat complicated legal questions as to right of way. Into the crisis of this situation was injected the following suggestion: A slow-speed, extremely heavy platform conveyor dipping gradually from the centre of the foundry floor, passing beneath the tracks, gradually rising again until it was about 4 feet above the shop floor and at that point dropping the wheels on edge into a runway, from which they could be distributed by rolling to the various machines. The suggestion was heartily welcomed. It was recognized that the first cost would be high and repairs particularly at the delivery end would be almost constant, but the greatest danger and the largest expense, "indirect and accidental," was entirely eliminated, as was also the risk of a serious accident. Too much emphasis cannot be laid on the necessity of simple massive construction of conveying machinery. Its design should have the safety factor of at least ten, and wherever possible its primary drive should be designed to give way at 50 per cent the strain safe for the rest of the apparatus. Ashes, sand and certain chemicals can be profitably handled in very few types of conveyor. Sand and ashes are peculiarly gifted in finding their way where they do not belong and in cutting the bearing surfaces all to pieces. Our friends of the Carborundum Company can tell us a great deal about their later experience.

One thing of interest in what we have seen to-day was at the Acheson Graphite Company. There a complicated system of crushers and conveyors was installed for handling their coke. One of their men told me to-day that they expected to abandon practically all except the elevators. The screw conveyor for coke, like nearly all types of conveyors for sand and for a number of other materials, is an extremely undesirable proposition. It is hoped that after the first elevation coke can be handled as we all endeavor to handle liquids or gases by gravity. It is proposed to take the coke up and dump it into a bin, and let it flow down to where it is wanted, instead of pushing it around by screw conveyors. Their early experience could hardly be framed in language fit for publication. Some of the apparently simple installations have in practice given almost endless trouble until finally some little unsuspected difficulty was overcome. Wherever possible, therefore, no plant should be made dependent upon the operation of any type of mechanical conveyor. There should always be a competing line that in emergency can be operated by the primitive beef and jaw bone. Perhaps no city of its size has as complete and varied an equipment of conveying devices as Niagara Falls, because few industrial communities have been so largely the development of progressive high-grade intelligence. In every case the difficulties have perhaps been overcome, but in almost every case they demanded plenty of overcoming.

Passing from the general question of plant layout to a few illustrations of the more detailed considerations, the lighting systems should in many cases receive far more attention than is granted them—and more intelligent attention. In one case the tonnage efficiency of $30,000 worth of plant and a department pay of $125 per week was increased more than 11 per cent by redistribution of 18 lights and addition of about 20 new ones; again, one building had over 120 lights and was as gloomy as a dungeon. The trouble was discussed with the Chief. Twenty dollars' worth of white enamel glaze paint was purchased and applied for reflecting surfaces. Two jumper lines were run to close the long circuits back to the mains. These cost $10. Fifty lights were cut out by substituting and relocating, regular cleaning and inspecting of the remainder instituted, and a new pulley put on the generator to raise the E.M.F. about 10 volts. Consequence, ample light at two-thirds the former cost.

The power plant has been discussed by authorities in all its phases, but a concrete illustration may be permitted. There were three boilers, a heavy steam-heating load and a 100 H.P., N. C. Corliss. "Another boiler was absolutely necessary." A man was sent out "to see just how best to accomplish the desired changes." He spent one week measuring drips, plotting pipe lines, indicating the engine, testing boilers and in the opinion of the management "doing similar stunts." Results, an economizer, a couple of recorders, a new stack, a hot well, and numerous pipe changes costing in the aggregate about $6000 in two years; one boiler *cut out* for reserve, a 40 per cent reduction in coal bill, and about 15 per cent greater production efficiency in two parts of the plant owing to ample hot-water supply. Saving, $3000 a year.

There is one point that we should not overlook, the "viewpoint." It is quite probable that no member of the Institute could devote two months of his time to the careful consideration of any manufacturing plant not under his own supervision without being able to make suggestions and recommendations to the owner which would many times repay the cost of his service. Familarity breeds content. An outsider comes into your plant with his experience, his viewpoint, and above all with an unbiased mind. He sees at a glance and the retina impresses upon his brain as new and deserving of consideration, things which have passed before the owner's eyes a thousand times, and which he has never *seen*. It is probably within the experience of all of us to have been able to suggest changes which have worked out into economies of many thousands of dollars a year in industries with which we were almost wholly unfamiliar. A policy of exclusiveness deprives the manufacturer of these benefits to a very large degree. Certain of the industries in which we are interested have recognized this fact, notably the metallurgical industries, and since doing so have taken forward strides which seem to place them on a different level. A prominent chemical manufacturer was invited to visit the acid plant of one of the smelters. At first he declined on the ground that he would not be at liberty to return the invitation. It was, however, repeated with the frank statement that no return invitation was desired. The manufacturer found practically every improvement and refinement of his own plant, and a few new ones. One of the questions seriously to be considered by us as managers for, or advisers of, manufacturers, is

the wisdom of a policy which certainly restricts development of an industry as a whole and probably decreases the profit of each manufacturer as an individual. It might well be the aim of this Institute to encourage, so far as the broadmindedness of employers will permit, this freedom of exchange of ideas and experience. Those who cannot be trusted to be fair in such co-operation are, we hope, still at the tender mercies of our membership committee.

It is recognized that any presentation of this character must necessarily be an outlined sketch of the subject. Also that the experience of any one man must necessarily be very incomplete and unevenly distributed. We should have a diagrammatic outline of the points to be considered in the general arrangement or layout of any industrial plant, with no expectation that it would be more than a first suggestion and with no hope that it is either the best arrangement or by any means complete. This should be done with the hope that the subject shall be discussed not only at this meeting, but that some section of it be taken up at every subsequent meeting and suggestions, alterations and additions made with a view to ultimately incorporating it and possibly using it as a framework for that general compendium of chemical engineering to which the Institute as a body stands committed.

Discussion

President McKenna:

I take some pride in that paper. I was not the author of it, but I think I could be called its stepfather. I knew that Dr. Grosvenor had the ideas and knowledge in his head, and I asked him to write it. I should like to hear some discussion.

Mr. Baker:

It is unfortunate very often and a great mistake for a man to start out to build a plant with an abundance of money, for the simple reason that we are unable to anticipate the conditions which will obtain in a plant later on, and consequently are very likely to waste a great deal of money. We have all learned by experience, I think, that perfection in any line is impossible, and although it may be a very fine idea to start with a completed plant, at the same time it is almost impossible to do so. I think we all know by experience that when we have outlined something we have been compelled later on to make changes and alterations

to suit conditions. And as far as real satisfaction in conducting any manufacturing or industrial operation is concerned, I think no one can gain more satisfaction and real pleasure out of a business than by starting on a small scale and building up gradually as occasion requires, and establishing a history which he can look back upon and see the steps that he has taken from time to time. Someone has expressed the idea nicely by saying that the best way to start a business was to begin boring with a small augur.

Dr. TAYLOR:

I do not know that I am very competent to speak on this subject. The lines laid down by the last speaker are interesting, and are the lines upon which most of us have had to work. I can, however, see some advantages in starting a new plant on new ground with clear ideas of what we want. I think we have a good exemplification of that in our trip to the Lackawanna Steel Company. The first three years of my chemical experience were spent in a steel works—the second Bessemer steel works started in this country. The design of that works was never what it ought to be, and although to my certain knowledge the plant has been rebuilt three times it was never right. On the other hand, the great United States Steel Corporation, with their large experience, went to Gary, Ind., and bought a large plot of land there which extends into the lake as well, and they have put on it a modern plant, with modern ideas, and with everything carefully arranged. I think it is an example of the fine buildings of a plant with large experience. Most of our chemical industries have had to grow in the way which Dr. Baker has indicated, and there are senses in which it is a most admirable way. On the other hand, I think if we are to attain what ought to be attained by chemical engineers, we have a good example before us in the practice I have cited at Gary, Ind., and our chemical plants should ultimately be built along those lines. If you start on a new piece of land with clear-cut ideas of what is wanted and practice along those lines, we shall have an ideal plant. Of course there are always leaks in such a case, but they should be looked after, and we should not put ourselves in a position in which these leaks can occur. Most of our chemical industries have grown up from small beginnings, and they have necessarily had to take that course, but I think we can well look forward to the time when a chemical industry is going to be set down on a new piece of ground, and carried through as it ought to be.

Dr. GROSVENOR:

The difference of opinion is perhaps due to the difference in the industries being discussed. The one is the steel industry, which is thoroughly developed, and which has been worked over in all its variations for years. The other, to which I think Dr. Baker refers, is rather the development of the diverse manufacture of a number of materials more or less interdependent upon one another, in somewhat variable quantities, and greatly dependent on market conditions. The manufacture of miscellaneous fine chemicals, particularly in small quantities, is hardly to be conceived as parallel to the steel industry, which turns out two, three or four products (or qualities of product, as the case may be) and in very much larger quantities. The ideal case for planning, as I have indicated, is the industry in which no one of the products is at all new. The careful planning of a plant using perfectly well-recognized methods, approximates what Dr. Taylor indicated all chemical industry may some day approximate, the methods employed at Gary.

Mr. LIPPS:

I would like to know one of the principal disadvantages of the conveyor.

Dr. GROSVENOR:

Wear and interruption on certain materials; coke and sand, and certain gritty, abrasive materials are peculiarly unpleasant to handle in conveyors—ashes, for instance. Unless the type is well selected, repairs become excessive. There is, perhaps, no material which creates more trouble than ashes, both because it is chemically corrosive and mechanically abrasive. The rougher and heavier the material, the simpler the method of handling should be made. There is no method of handling either ashes or sand that approximates the trolley rail and the grab-bucket in directness and satisfaction both as regards the repair factor and the operating factor.

Mr. LIPPS:

I thought you referred to materials in general.

Dr. GROSVENOR:

It is more general than we like to admit. Heavy tonnage is usually the pre-requisite.

THE FITZGIBBONS BOILER

By JEROME ALEXANDER

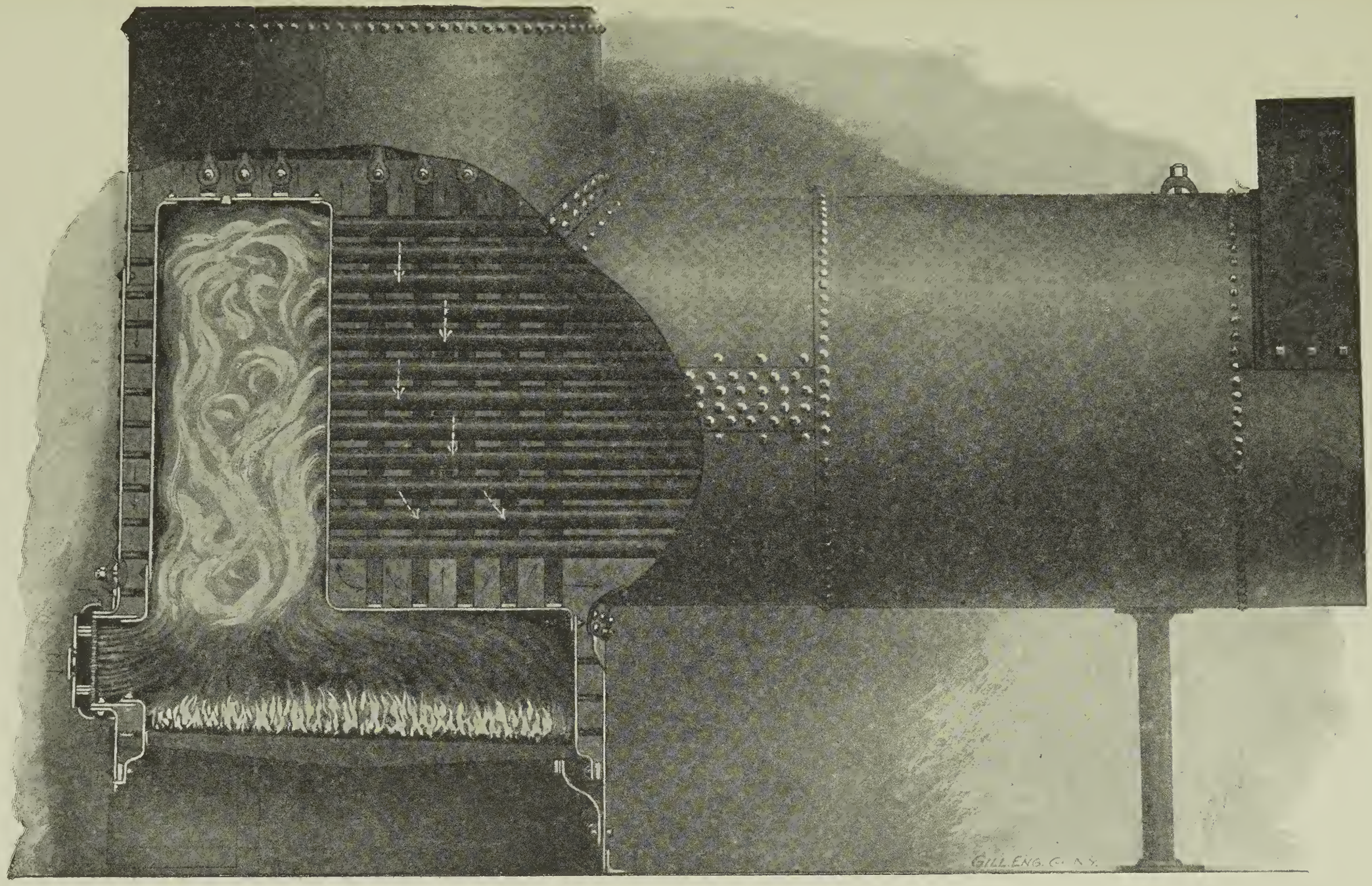
Read at the New York Meeting, Dec. 9, 1910

HAVING had about ten years' experience with a medium sized boiler of this type, and a shorter but equally satisfactory experience with another slightly larger unit, it occurred to me that a brief description of the Fitzgibbons boiler, and the principles of its construction and operation may be of interest to the members of this society. The total absence of outside and inside brick work, the ease with which the boiler may be moved, its quick steaming and capacity for overload, and its economy in coal consumption, are all features which render it of interest, especially to chemical manufacturers who use at intervals large quantities of live steam for heating solutions, etc.

This boiler is illustrated in the accompanying cut and is a departure from the ordinary types in use. It combines the internally fired principle and in part the economy of floor space of a vertical tubular boiler, with the horizontal tubes of the return tubular type, but eliminates at the same time some of their acknowledged serious defects.

The principle of combustion in a Fitzgibbons boiler is a new feature in boiler designing, and makes this design unique in this respect. A large combustion chamber is provided directly over the furnace and in the front, or firing end, of the boiler so that the gases distilled from the burning coal on the grates are brought back toward the fire door, where sufficient air may be introduced to consume them thoroughly in the combustion chamber, leaving only the products of complete combustion to enter the tubes.

A very much higher temperature in the combustion chamber results from this mixture of air and unconsumed gases, meeting as they do in a part of the furnace where the gases rising from the coal on the grate have not been brought in contact with any of the heating surfaces of the boiler, so that free carbon in the



The Fitzgibbons Boiler.

gases is thoroughly consumed and the temperature of the furnace increased from 700 to 1000° F. above the ordinary furnace temperatures.

The perfect combustion in the combustion chamber, resulting from the admixture of air with unconsumed gases, reduces the amount of smoke from semi-bituminous coal to a minimum, and cannot be equalled in other types of boilers, unless they are fitted with special smoke preventive devices.

Another advantage lies in the location of the combustion chamber full of burning gas at an exceedingly high temperature. This chamber is carried up to within a short distance of the water level in the boiler, and consequently transmits the final increment of heat necessary for the rapid generation of steam in the most desirable part of a steam boiler.

The construction is extremely simple, the tube being flanged and riveted to the vertical shell, the opening in the latter being cross-braced to give it the strength of a complete cylinder. In addition, the vertical shell is screwed stayed to the furnace and the combustion chamber, so that all of the strength of this complete body is imparted to the vertical shell. Experience with these boilers under all conditions of excessive duty has demonstrated beyond a doubt that they are equally strong in all of their parts. The boiler is constructed entirely of cylindrical shells and offers no restriction to the circulation of the water in it, with the result that it is not only a remarkably quick steamer, but it furnishes exceptionally dry steam.

The tube barrel is entirely submerged and the water therein, necessarily rising to the highest water level in the boiler which is in the vertical shell, displaces the water in the leg about the furnace, so that an exceedingly rapid circulation is effected in a clearly defined and unchanging path.

The circulation in a boiler of this type is exceedingly rapid, so that the heat of the products of combustion is quickly absorbed by the heating surface of the tubes, which have been shortened to about half the length of the tubes in a locomotive boiler, and at the same time the gases leave the uptake at as low a temperature as is consistent with the best efficiency.

The boiler is susceptible to many variations to meet the varied conditions of fuel and draft. For culm or refuse anthracite, brick extension furnaces may be used, and in a plant of 3000

H.P. recently installed with a chimney 175 feet high, an excess of 35 per cent in H.P. above rating was obtained with natural draft, burning rice coal, and an efficiency of 80 per cent. Its design makes it especially applicable over heating furnaces for utilizing waste heat gases, and a number of installations have demonstrated a remarkable increase in the power developed as compared with the types of boilers ordinarily used for this purpose, as the result of more complete combustion.

The location of the fusible plug in the crown sheet of the combustion chamber is a safeguard against any possible injury from low water, for as the chamber is at an exceedingly high temperature, the fusible material in the plug melts at once if exposed, and the escape of steam directly upon the grates checks the fire instantly to such an extent that it is impossible to injure the boiler. Absolute immunity from explosion from low water is thus provided.

As a quick steamer, although a fire tube boiler, it exceeds any of the standard water tube types. This was demonstrated in a competitive government test, the result of which led to the adoption of this type for use in the fog signal stations where quick steaming was of paramount importance.

The grate being circular is more efficient and much easier to fire than a rectangular grate with square corners. This fact together with the perfect combustion effected over the furnace enables us to get an efficiency of 80 per cent under ordinary operating conditions when using good coal. The economy in floor space is fully 40 per cent as compared with any type of brick set boiler with horizontal tubes.

Being internally fired, the boiler is free from brick fire box and exterior brick setting, thus avoiding the annoyance and expense of frequent repairs at most inopportune times. The first cost of the Fitzgibbons boiler is about the same as that of a horizontal tubular boiler properly set; but when the tubular boiler is moved, its brickwork becomes practically a total loss, whereas the Fitzgibbons boiler may be moved without loss, and is ready for immediate operation.

Furthermore, a suitable covering of asbestos or magnesia minimizes radiation through the boiler shell as compared with the loss of heat sustained in the brick set boilers by radiation through the brick work and cracks which always appear in the masonry.

THE MANUFACTURE AND PROPERTIES OF HYDRATED LIME

By RICHARD K. MEADE

Read at the New York Meeting, Dec. 7, 1910

Composition of Hydrated Lime

To a product recently placed on the market which is made by mechanically slaking lime, the name " hydrated lime " is given. It consists of a dry fluffy powder, nearly all of which will pass through a very fine screen, and is essentially calcium hydrate and magnesium hydrate mixed with a greater or less amount of such impurities as silicia, iron oxide and alumina.

Theoretically, 56 parts of lime unite with 18 parts of water. If more than 18 parts of water be added to 56 parts of lime the quantity of water in excess of 18 parts will either be driven off by the heat generated, which amounts to 1500 calories per kilo of lime, or, if much in excess will remain with the slaked lime. The excess of water of course does not combine with the lime, but merely exists as water, forming with the slaked lime a wet mass or putty. This is what takes place when lime is slaked by the mason in the mortar box. If the proportions of lime and water are exactly or nearly 56 to 18, and the mixture of lime is thoroughly worked so that the slaking is complete, all the water is absorbed by the lime and the product is a dry powder. This dry slaked lime is the " hydrated lime " of commerce.

For quite a number of years there have been upon the market crude products which resulted from the slaking of the lime in piles on the ground or floor by the application of water. In most instances, the water added was insufficient to change all of the lime to hydrated lime and some of it always remained as the oxide. Some carbonate was also always formed, and if the lime was air-slaked the carbonate was considerable. These limes, generally

speaking, did not give satisfaction for mortar purposes owing to the fact that the hard-burned portions would not slake by such treatment. These so-called hydrated limes when made into mortar and used for finishing caused cracking of the wall and what is technically known as "blowing," owing to the fact that when lime slakes it expands, and that this unhydrated lime slaked after being applied to the wall and after the plaster had hardened, causing a change in volume of the plaster. Most of these hydrated limes soon became known as fertilizer limes, because found most suitable for this purpose, as they could be applied to the field by means of a wheat driller, owing to their being in the form of a coarse powder. The analyses below show the character of some of them.

	No. 1.	No. 2.
Calcium hydrate	69.10	53.96
Calcium carbonate	13.62	31.13
Calcium sulphate	n. d.	1.58
Magnesium hydrate	4.24	3.26
Silica	9.84	7.88
Iron oxide and alumina	3.02	2.34
Fineness, passing No. 200 sieve	41.5 %	49.0
Fineness, passing No. 100 sieve	58.0 %	59.0
Fineness, passing No. 20 sieve	.....	78.0

Recently several processes have been devised for mechanically slaking lime so that it can be placed upon the market in a dry powder and by which the slaking is done sufficiently well to allow of the use of the product in plastering, for the manufacture of sand lime brick, in Portland cement mortar, etc.

The chemical composition of hydrated lime of course depends entirely upon the composition of the lime from which it is made. High calcium limes slake much more quickly than do high magnesium limes and it is more difficult to make hydrated lime from such quick limes, owing to the fact that it is hard to properly mix the lime and water in the short time allowed. In slaking high calcium limes, a great deal of heat is developed, and this tends to drive off the water before it has a chance to combine with the lime. The heat also tends to scorch the lime or change it from an amorphous to a crystalline powder, which latter form does not seem to

work as smoothly under the trowel as the former. The same change also seems to occur when the water is added in two stages. Limes which contain a large percentage of silicious and argillaceous matter also slake much more slowly than do pure limes. Generally speaking, only pure limes should be used for hydrated lime. Both magnesium limes and high calcium limes may be hydrated to advantage, and the uses of the two hydrates are identical with the uses of the two varieties of lime respectively. Below will be found the analyses of some American hydrated limes:

ANALYSES OF HYDRATED LIMES

	No. 1.	No. 2.	No. 3.	No. 4.
Calcium hydrate	90.11	83.13	56.26	45.10
Calcium oxide	none	1.87		
Calcium carbonate	2.25	10.42	7.12	20.04
Magnesium hydrate	1.39	.....	2.17	8.07
Magnesium oxide	.....	1.27	31.45	25.02
Silica	2.05	0.46	1.49	0.34
Oxide of iron and Oxide of alumina	1.01	0.44	0.73	0.18
Moisture (hygroscopic)	3.10	2.56	0.90	0.73

Manufacture of Hydrated Lime

Lime which is to be hydrated need not be burned so thoroughly as lime which is to be placed on the market in bulk. Where lime is transported in lumps it is found necessary to partially vitrify the outside of these latter to prevent their falling to pieces in the cars. Where lime is to be hydrated, however, this is unnecessary, and the softer it is burned the better, provided that the larger portion of the limestone is converted to the oxide. This may be effected at a temperature of less than 1000° C. Where lime is to be hydrated, therefore, slow-burning kilns should be employed.

Processes for the manufacture of hydrated lime practically all consist of three stages: (1) the crushing of the lime, (2) the mixing of the lime and the water, and (3) the separation of the hydrate from the unhydrated portion, or else the grinding of the latter.

The hydrating plant itself is usually located immediately adjacent to the lime kilns. The lime is drawn from the kilns and without allowing it to air-slake or to cool further than is necessary

to prevent its setting fire to the belts which are used to convey it, is dumped either directly into the crusher or else on to a belt which discharges into the latter. Where only a few kilns are employed, the crusher may be located at a central spot convenient to all, but where there are six or more kilns a belt conveyor running along in front of the kilns and below the cooling floor will be found most economical. The lime should be discharged on to the belt through openings in the floor, which when not in use are to be covered. The crusher should be located with its top flush with the floor. To prevent careless workmen falling into it, a coarse grid made of iron bars about 8 inches apart should be made to fit the opening and fastened to this latter so that it may be easily removed for repairs.

The crusher usually employed consists of some form of rotary or pot crusher. Gyratory and jaw crushers are never used, as they clog up with such soft material. The Sturtevant "open-door" crusher is probably used at more plants than any other form. These crushers reduce the lime to such a size that it will all pass a one-half inch ring screen. This is as fine as it is necessary to reduce it for either the Kritzer or the Clyde hydrator. With some other forms of hydrators, however, the lime is actually ground before being fed to the hydrator. This may be done by any form of grinding mill and is sometimes carried so far as to make the product pass the 20-mesh screen. The sizes of rotary crusher usually employed are the Nos. 1½ and 2 Sturtevant. The smaller of these will easily take care of 60 to 75 tons of lime per 10-hour day.

The crushed lime is transported from the crusher to the hydrator on a belt conveyor. This usually discharges into the foot of a bucket elevator which lifts the material into a large bin above the hydrator. This bin should be of steel or other non-inflammable material, as the quick lime might set fire to wood. Sometimes wooden bins lined with asbestos board and metal sheets over this are used, but the steel bins are better and almost as cheap as these latter.

Mechanical Hydrators

All hydrators may be divided into two classes, (1) *continuous* hydrators and (2) *batch* hydrators.

Only one form of continuous hydrator is used to any extent at the present time. This is the Kritzer hydrator (see Fig. 1).

This hydrator consists of a number of cylinders about 12 feet long and 20 to 30 inches in diameter, mounted one above the other on a steel framework. These cylinders are from four to six in number and the lower ones are larger in diameter than the upper ones. Each cylinder is provided lengthwise with a central

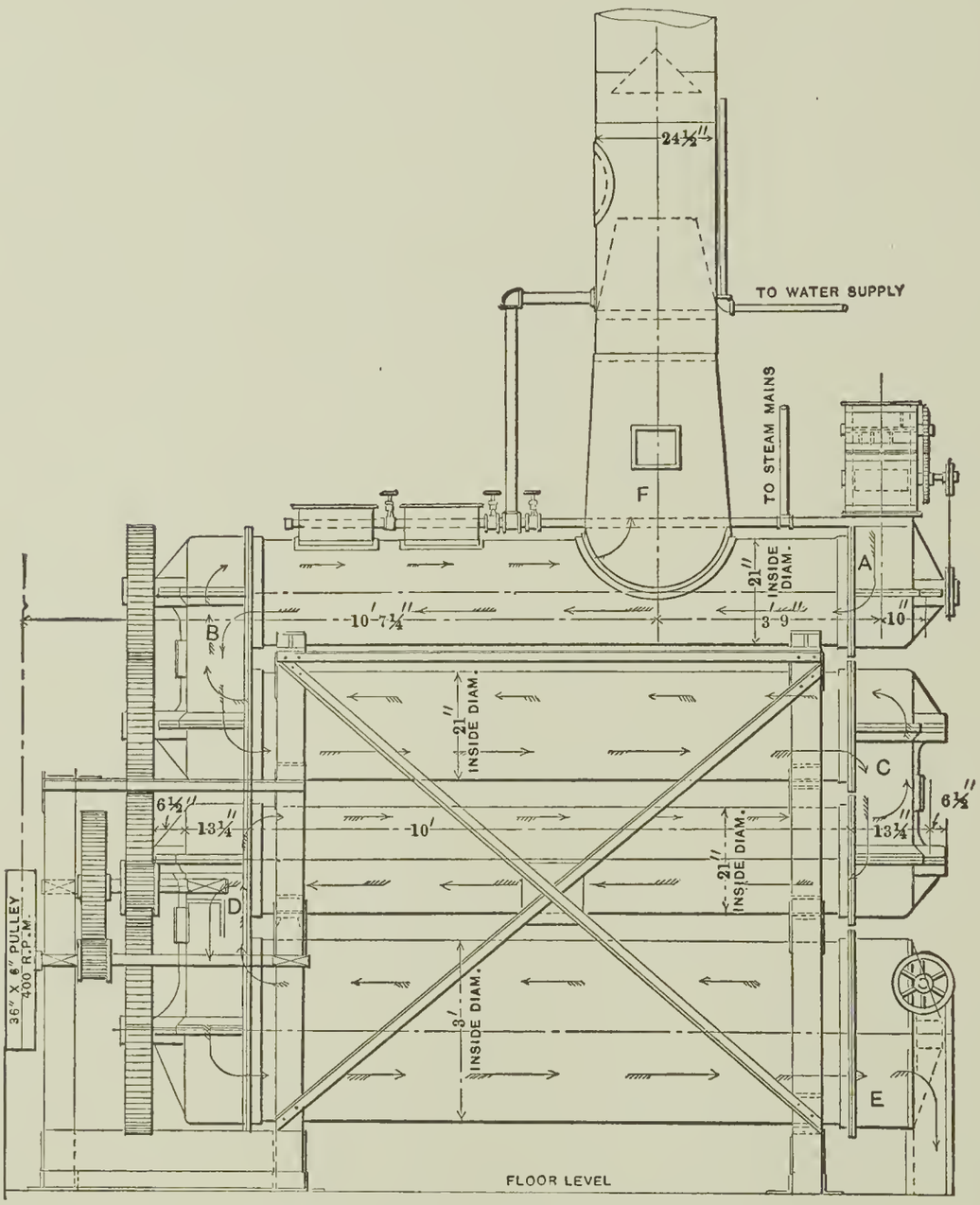


FIG. 1.—Kritzer Hydrator.

shaft to which are fastened a number of paddles. These paddles are actuated by means of gearing at one end. The cylinders are closed at both ends with an opening on the lower side of one end and the upper side of the other end, and are placed with the lower opening opposite the upper opening of the cylinder beneath it so that the cylinders discharge one into the other. The lime is fed

into the upper cylinder in a continuous stream and here water is sprayed upon it, the amount being regulated by a needle valve. The moist lime is worked by the paddles and passed through the upper cylinder to the next lower one, and so on down until it eventually works its way through the bottom cylinder and out of the hydrator. When discharged from this latter, the hydration is complete and the hydrated portion of the lime is in the form of a dry fluffy powder.

Considerable heat is of course developed in the process, the temperature of the top cylinder being from 80° to 90° C. This unquestionably helps to hydrate the lime quickly, otherwise much of it would remain unslaked. The steam which is generated passes from the lower cylinders up through the upper ones and also helps to hydrate the lime. Ventilation is necessary, and this is provided by means of a tall stack connected with the upper cylinder. Considerable dust is formed in the hydrating. This if allowed to pass out of the stack would cause considerable nuisance in the neighborhood. To prevent this there are located in the stack a water-jet and a number of cones over which the water passes. This device serves to collect this dust, while the water uniting with the latter forms milk of lime, which is allowed to enter the hydrator and help along the process of hydration.

The amount of water fed to the hydrator is controlled by a needle valve provided with a pointer and dial and is supplied by a pump. The pump is run by means of a chain from the hydrator and when the latter stops, the pump stops, preventing the flooding of the hydrator by a careless operator. The lime is fed into the the upper cylinder of the hydrator in a steady stream by means of a mechanical feeder, and by regulating the valve the attendant can add the proper amount of water to slake the lime. If too much water is added, the hydrated lime will leave the hydrator wet and will not screen properly. If too little water is used, the lime will be unhydrated and this may be detected by the fact that it heats up when more water is added. An opening, closed by a slide, is provided in one of the top cylinders for drawing samples. The operations of the top cylinder can also be watched through openings covered by slides in the top of the top cylinder. The operator requires some practice to properly manipulate the hydrator, but any intelligent workman can be taught in a few weeks' time how to run the machine and turn out a good product.

The capacity of a hydrator depends largely upon the kind of lime hydrated, how hard the lime is burned, how much silica it contains, etc. A six-cylinder Kritzer hydrator should hydrate from 4 to 5 tons of high calcium lime per hour and slightly more than this amount of magnesium lime, which hydrates more easily.

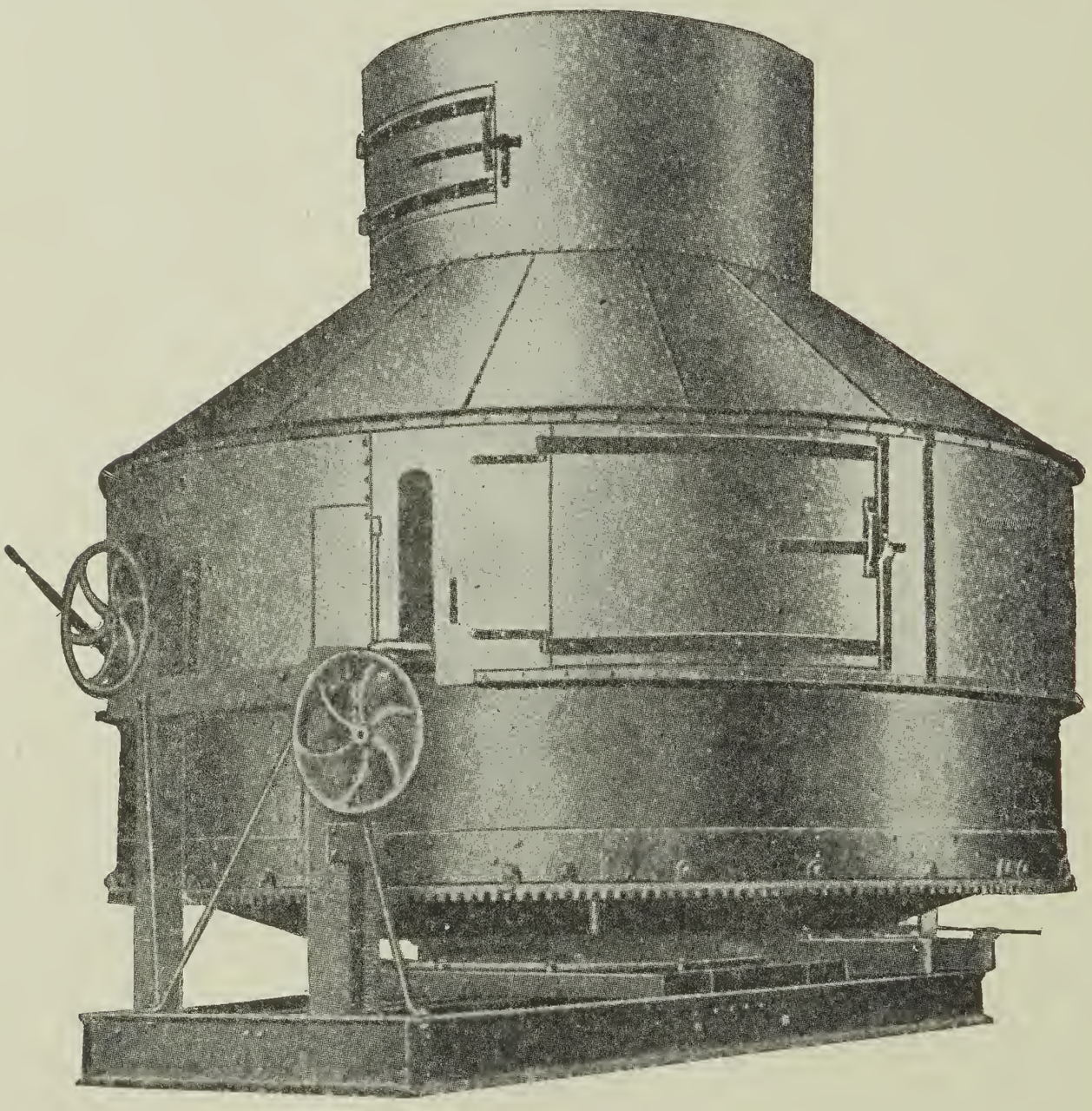


FIG. 2.—Clyde Hydrator.

The Clyde hydrator (see Figs. 2 and 3) is a " batch " machine, in which the amounts of lime and water are weighed in separate charges. The hydrator itself consists of a steel pan 10 feet 6 inches in diameter and 20 inches high, resting on a ball bearing. This pan is revolved by means of a gear and pinion located on the under side, and is provided with a hood top and a stack. This top does

not revolve. In the center of the pan is a circular opening which is closed by a metal rim. This rim is raised when the lime is to be discharged. Suspended from a stationary framework above the pan are a number of plows which reach to the bottom of the pan. The lime and water are accurately weighed. The lime is introduced into the pan through an opening in the side of the hood and the water is spread upon the latter by means of a sprinkler pipe running across the pan, during which time the pan is revolved. As the pan revolves the plows turn the lime over and over, thoroughly mixing the lime with the water. The heat generated in the process evaporates all of the free moisture, leaving the product

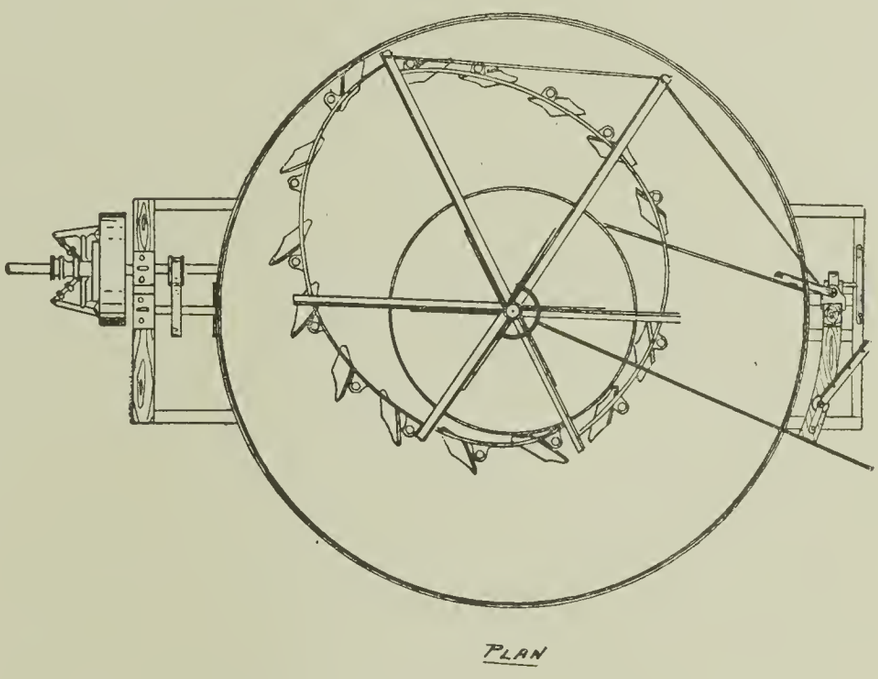


FIG. 3.—Clyde Hydrator.

dry and at a temperature of about 200° F. When the operator deems that the hydration is complete, which he determines by drawing a sample, the central rim is raised. This exposes the opening in the center of the pan. An automatic scraper attached to the framework is now lowered and the pan revolved. This scraper forces the lime to the center of the pan and consequently through the opening in the latter. It falls from the opening into a steel hopper and is conveyed from this to the screens by means of a bucket elevator or other conveying device.

The plows are arranged in the form of an ellipse (with one of its axes about the center of the pan), so that they completely cover the whole surface of the pan. The plows on one side of the

ellipse are right hand, and on the other left, so as to work the lime thoroughly (see Fig. 3).

The lime is usually weighed in batches of 1500 to 2000 pounds, and the process requires from 10 to 15 minutes from the time the lime is dumped into the hydrator until it is emptied and ready for another charge, so that the capacity of the hydrator is from about 3 to 5 tons of lime per hour.

The best arrangement of a plant for this hydrating system is to locate the receiving bin for the quick lime in the roof, then below this the scales, which should be of the hopper type and controlled by a lever, and below the scales the hydrator. The hydrator should dump into a pit or on to a belt and the lime elevated thence up to the small bin above the screens. These latter should be located above the packing machine bin.

A number of other hydrators are in use. These consist for the most part of closed cylindrical drums into which the lime is introduced through an opening in the side, which is then closed. Water is introduced by means of a pipe running through a hollow shaft which supports one end of the drum. The drums are revolved while the water is being added and for some time afterwards. In some forms of drum hydrator, steam is introduced in place of water, and in one system of hydrating two drums are used, in one of which water is employed to partially hydrate and in the other steam to complete the hydration. A hydrator consisting of an inclined rotary cylinder has also been employed, in which the lime and water are fed in continuously at the upper end while the cylinder revolves. The lime and water are mixed together by the revolving of the cylinder, and the mixture gradually works its way down through the cylinder, and out at the lower end, when hydration is completed. In still another system an excess of water is used which is evaporated in dryers by means of the waste heat from the lime kilns.

Practically all of these latter systems are used at but one plant, usually that of the inventor. The drum hydrators give an excellent product and, when steam is used, one which is thoroughly hydrated and consequently well suited for the most exacting class of work. They are, however, much less economical of operation as far as costs go, than the Clyde and Kritzer systems. They all require screening or grinding of the product if this latter is to be fine.

After passing through the hydrator, that portion of the lime

which has been slaked is in the form of a fine fluffy powder, all of which will pass through a very fine sieve. The total product as it comes from the hydrator, however, always contains lumps or cores. These consist of three things: First, unslaked lime; second, unburned limestone, and third, silicious matter in the limestone. If the lime has been burned very hard, there will be a considerable amount of core consisting of unslaked lime. If the lime has not been burned very hard, the cores will consist of unburned limestone, while with impure limestones the cores will consist largely of silicious matter. Where the lime has been normally burned, it usually consists of all three. Below will be found the analysis of the cores or screenings from a high calcium hydrate.

ANALYSIS OF CORES FROM HYDRATED LIME

Silica	28.10
Iron oxide and alumina	3.06
Calcium oxide	16.16
Calcium carbonate	42.12
Calcium hydrate	8.10
Magnesium carbonate	1.26

For the better grades of hydrate, it is usual to separate out this core by means of screens. These may be of several patterns; among those most employed are the Columbian screen, the Newaygo separator, both of which are inclined wire cloth screens, and the air separator. In Europe the air separator is chiefly used, but in this country the screen.

The two forms of screens most used in this country for screening hydrated lime are the Newaygo separator and the Columbian separator. Both of these consist of an inclined screen mounted at an angle of about 45°. In the case of the Newaygo separator, Fig. 4, the screening device consists of two sets of wire-cloth screens, one, the upper, of coarse mesh which serves as a scalper to take off the large pieces and protect the lower screens, and one, the lower, of finer mesh which serves as the final separator. On this fine-mesh screen are mounted steel bands running from the top to the bottom. Short steel bars rest upon these bands. A shaft actuated by power runs across the top of this screen, and on this shaft are hinged short pieces of iron to form hammers. When the shaft turns, these hammers strike the steel bars resting on the fine screen and

the jar serves to bounce the fine material through and keeps the screen from clogging.

With the Jeffrey Columbian separator, in place of bouncing the screen, this is made to oscillate back and forth. This motion is produced by means of an eccentric and toggles. With both forms of screen, the material to be separated is fed in at the top of the screen by means of a screw conveyor, which can be adjusted so as to feed the material uniformly along the width of the screen. The coarse material, of course, rolls over the screen and the fine

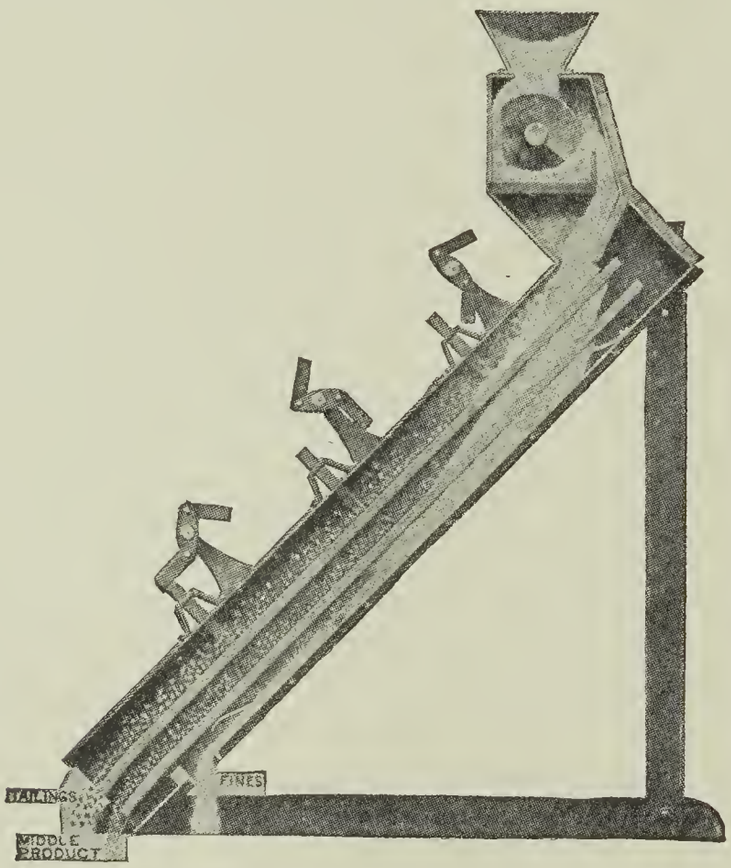


FIG. 4.—Newaygo Separator.

passes through. Both screens are cased so as to prevent unnecessary dust in the mill, but in spite of this when used for hydrated lime it is usually found necessary to box them up. The fineness is regulated by the inclination of the screen and also by the wire cloth used, which is always much coarser than the product—for instance, the 30-mesh screen is usually used for hydrated lime, practically all of which will pass the No. 100 mesh sieve. These screens require very little power to operate, one to two horse-power being sufficient.

There has been some disposition of late to replace the screen by pulverizing mills, the object being to utilize the tailings and so

increase the output of the plant. When this is done the entire product of the hydrator is passed to the pulverizer. The hydrated portion is, of course, already sufficiently fine and the mill is only required to grind the cores or what would ordinarily be the tailings from the screens. If these tailings consist of unburned limestone and silicious cores only, the grinding of these, of course, merely serves to increase the impurities in the lime and in no way injures it for building purposes. Indeed in some instances these cores consist of silicious lime compounds with hydraulic value, and grinding them in actually improves the lime. At one plant where the lime contains from 10 to 20 per cent finely divided silica, it was found that when these cores were ground in with the hydrated lime, the product had decided hydraulic properties.

Similarly when these cores consist, as they sometimes do, very largely of unslaked lime, no objection need be felt to their use for most purposes, as the finely ground lime will usually hydrate comparatively quickly; promptly enough at any rate for the use of the lime for mortar purposes. Where the lime, however, is to be used for sand lime brick, it must contain practically no unhydrated lime, and for this purpose the screens give much the better product. The screens, however, are troublesome, and when they can be dispensed with this had better be done.

Where the screens are not used the lime passes from the hydrator to the grinding mill, where it is usually ground so fine that at least 80 to 90 per cent of it will pass the No. 200-mesh sieve. Usually a much finer product is obtained with the screens than without them, although any one of the mills mentioned below may be set to give a product fully as fine as the screens. An ideal installation would consist of a set of screens followed by some form of grinding mill to take care of the cores. The lime passing the screens should be used for the manufacture of sand lime brick, for finishing work, etc., while the cores are ground finely, mixed with a certain percentage of hydrated lime, which may or may not be made to pass the screens, and used for mortar work and fertilizer purposes.

The mills usually employed for grinding either the tailings only or the entire product are the Fuller-Lehigh, and the Raymond mills. Where the former of these is employed, only two of the four balls are needed. With each of them the separating is done by air. A full description of the Fuller-Lehigh mill will be found in the Transactions of the Institute, Vol. I, p. 109.

The Raymond mill consists of a horizontal ring or die against which are made to revolve four rolls suspended by a shaft from a revolving framework. The fine-ground material is sucked out by means of a blower and allowed to settle in a cone-shaped reservoir.

Packing Hydrated Lime

Practically all hydrated lime is packed by means of the Urschel-Bates automatic sacking machines. These allow it to be packed very rapidly and with respect to the weight accurately and with a minimum of dust. This system is the invention of Mr. A. M. Bates, and was first used for hydrated lime at the plant of the

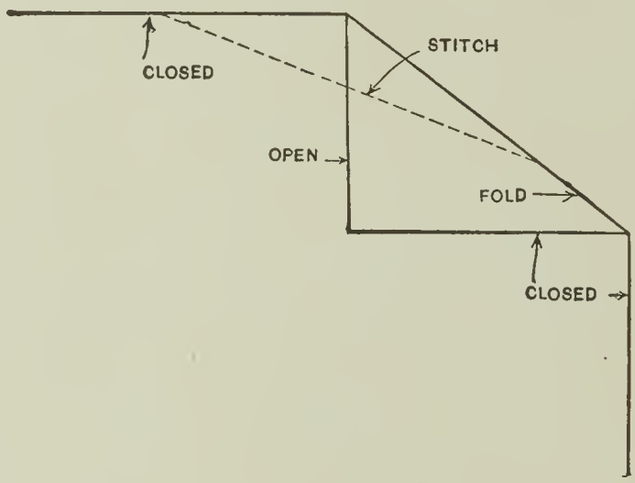


Fig. 5.—Bates Valve Bag.

Woodville White Lime Company, in Ohio. It primarily depends upon a novel bag, of which the fundamental feature is a valve in one corner, which projects into the bag as is shown in Fig. 5, and is made by ripping and tearing down a corner of the bag and sewing up on the dotted line shown in the illustration. When pressure is applied to the valve from the inside, as is the case when the bag is filled and reversed and the lime comes against it, the valve closes.

With this bag, the operation of filling, which ordinarily consists of putting the material in the bag and then tying it, is reversed and instead, the bag is first tied and then filled, the filling being done through the valve by means of the special bagging machine described below (see Fig. 6). When paper sacks are used, these are closed at both ends in the bag factory, where the valve is also placed in the bag by folding and pasting. The cloth bags are tied at the lime plant on a special machine which is capable of handling 25 bags at once. With this appliance a boy can tie between four and five thousand bags in a day of ten hours.

To fill the bag the operator has only to throw the self-closing valve of the finished bag over the tube of the bagging machine (Fig. 6). This he does with a quick one-hand motion. A lever is then opened which permits the material to flow into the bag in a thin stream about one inch in diameter. When the exact quantity of lime desired has been fed into the sack, the weight of the bag and contents offsets a counterpoise at the opposite end of an evenly

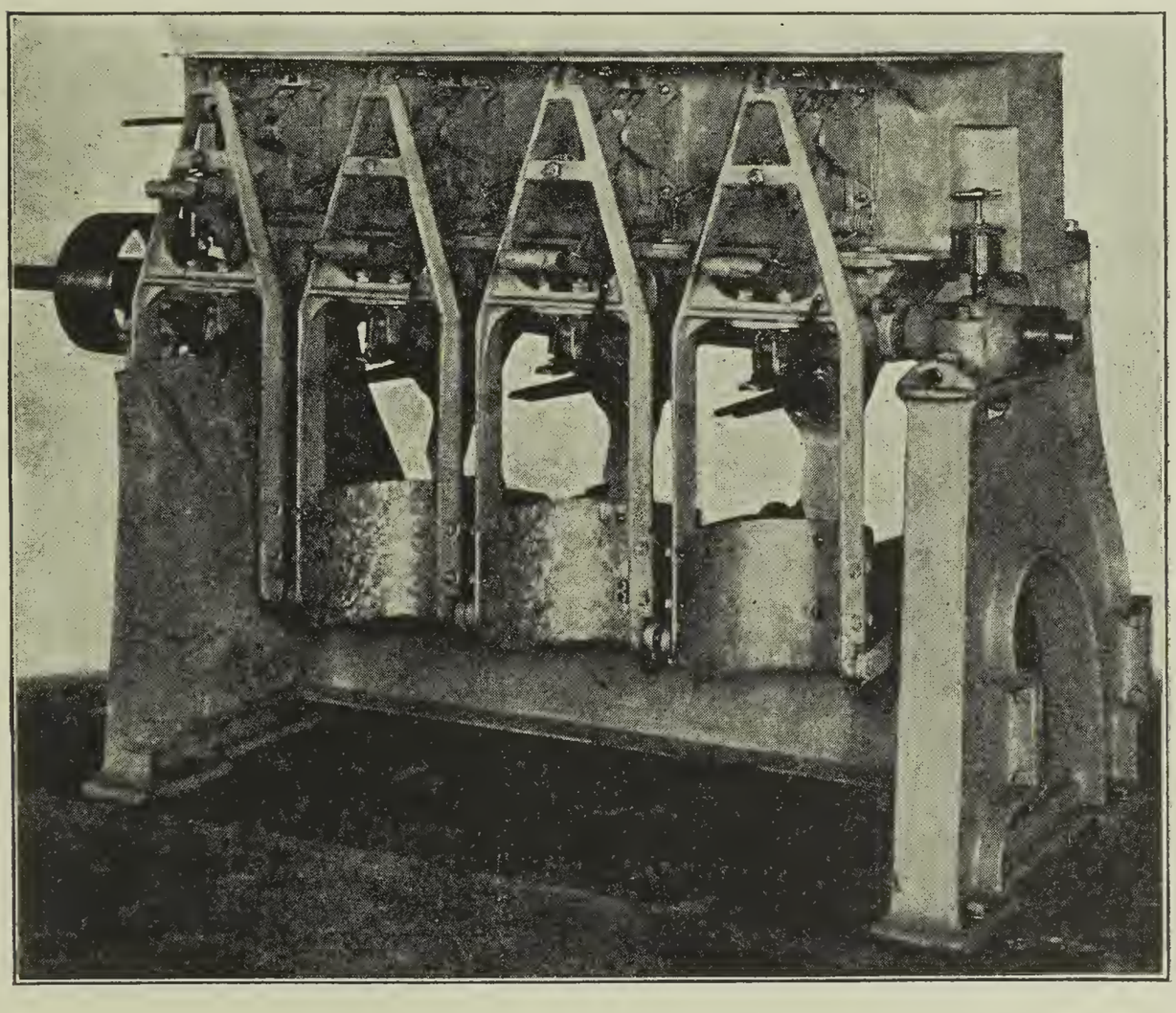


FIG. 6.—Bates Valve Bagging Machine.

balanced beam; the bag, of course, begins to fall and simultaneously with this the flow of material is shut off. The bag has only to move one-eighth of an inch for this to take place, when the bag has been filled it is tilted down to the truck and wheeled into storage or to the cars.

Hydrated lime is usually packed in paper bags holding 40 pounds to the bag, or else in burlap sacks or cotton sacks holding 100 pounds each. Paper bags are not returnable, but the cotton and burlap ones are.

Cost of Plant and Hydrator

A plant consisting of one Clyde hydrator and the necessary screening, packing and conveying machinery, for the hydration of magnesian limes having a capacity of 2 to 3 tons per hour, can be equipped for about $6000. This does not include buildings, which if of frame would probably add $1500 or $2000 to the above sum. A plant of double this capacity and containing two hydrators could be built for about $8000 exclusive of buildings. The first plant would require about 30 horse power and from three to five men, while the second plant would employ from four to six men and require from 40 to 50 horse power. The equipment of a plant for the hydration of high calcium lime by the Kritzer process, having a capacity of from three to five tons per hour, would cost from $12,000 to $16,000, to which must be added the cost of the buildings. From four to five men would be required for the operation of the plant and about 50 horse-power would be needed.

As to the cost of hydrating lime, manufacturers commonly calculate that the cost of hydrating lime is borne by the increase in product. For instance in hydrating a ton of pure high calcium lime (2000 lbs.) there will be obtained 2600 pounds of hydrated lime, taking into consideration the cores. The quantity of hydrated lime which will actually be obtained, however, depends, of course, upon the amount and treatment of the tailings. If these latter are ground up, a ton of lime will produce from 2400 to 2600 pounds of hydrated lime. Where the hydrate is sieved, however, a ton of lime will seldom produce more than a ton of hydrated lime.

Below is a statement of the cost of hydrating lime, where the tailings are ground in with the lime.

Cost of Hydrating 30 Tons Lime

1 Engineer and fireman combined	$2.00–	$2.50
1 Hydrator and mill attendant	2.50–	3.00
1 Man at crusher at $1.40 to $1.75	1.40–	1.75
2 Men as packers at $1.60 to $2.00	3.20–	4.00
Power, lubricants, etc.	1.50–	2.00
Cost of hydrating 30 tons	$10.60–	$13.25
Hydrate produced (tailings included)	40 tons.	
Cost per ton	$0.265–	$0.331

BLEACHING OF OILS WITH FULLER'S EARTH

By DAVID WESSON

Read at the New York Meeting, Dec. 9, 1910

THE literature of Fuller's earth and its applications is very meager. The earliest reference to its use as a bleaching material for fats and oils appears in the Bulletin of the Department of Agriculture, Division of Chemistry, No. 13, part 4, "Lard and its Adulterations," by H. W. Wiley, in 1889, where a brief description is given under the heading of "White Cotton-seed Oil." The twenty-first annual report of the U. S. Geological Survey, 1889–1900, gives an account and analyses of various Fuller's earths, together with the methods of using them. The only satisfactory article on the chemistry of Fuller's earth and its uses which the writer has been able to find is Prof. Parson's comprehensive paper published in the Journal of the American Chemical Society, June 26, 1907, vol. 29, p. 578. This article covers very fully the statistics of production, preparation of the earth and its chemical peculiarities.

The first account of its use sounds almost mythical, and so far as the writer is aware, has never been published. The facts however, came to him from men now living and can doubtless be authenticated.

Somewhere about 1878 or 1880 a Chicago broker introduced a Turkish gentleman from Algeria or Morocco to the firm of N. K. Fairbanks & Co., Chicago. This man claimed that in his native land it was the custom to agitate olive oil with clay in order to improve its color, brilliancy and flavor. Some experiments made with various clays showed that they possessed the property of removing the color from yellow cotton-seed oil and other fats. Experiments were made with clays obtained from all parts of the United States, also with some European varieties,

with the result that English Fuller's earth of a certain character was found to give the best results.

The method of application was very simple. The oil and earth were agitated together and then allowed to settle over night. The bleached oil was pumped off in the morning and the oily clay run out into the tanks, where it was boiled up with water and a large portion of the oil recovered by skimming. Incidentally, most of the color which had been absorbed by the earth went back into this oil. The sludge remaining in the tanks was boiled up again and submitted to pressure between iron plates in a knuckle-joint press.

In testing different samples of earth in the laboratory nothing was more natural than to use filter paper to secure a rapid separation of the oil from the earth. This suggested the use of the filter press, which was adopted some time about 1880 to 1882, from which period dates the successful use of Fuller's earth for oil bleaching in this country, and probably in the world. Like many other good things, it has been kept more or less of a trade secret for many years. At the present time the use Fuller's earth is so widely extended that few manufacturers have any advantage over others except in refinements and successful application of the method.

The efficiency of a given sample of Fuller's earth for the bleaching of any particular class of oil can only be determined by actual test. Chemical analysis shows comparatively little except the presence of soluble iron salts, which are always to be avoided. It will also show the presence of too much alkali. It is so much simpler, however, to make a laboratory bleach test that in practice a mineral analysis is seldom resorted to. A bleach test is quite empirical and consists in stirring weighed amounts of oil and Fuller's earth for a regular period at a temperature of about 100° C. The oil is then filtered and compared in color with results obtained under exactly the same conditions by means of a modified Lovibond tintometer, the colors being recorded as shown on the glasses of the Lovibond color scales. In practice the only colors used are red and yellow.

Regarding the soluble iron salts, a number of years ago we obtained an apparently very fine lot of Fuller's earth which came from a section in Georgia. It gave excellent results. The oil came up white, but after standing in the storage tanks for

a month or two, it went back in color. This was due to small quantities of ferrous sulphate present in the earth, and apparently the formation of a ferrous compound, which by oxidization caused the oil to darken up several shades. Now we always test the earth for soluble iron.

In comparing the bleaching properties of two earths the question of grinding should always be taken into consideration. The following results, obtained on the same oil by using in the first set of tests the commercial earth as received and in the second test the same earth after it has been bolted through a 200-mesh sieve, give a striking illustration of this point:

	1%		2%		3%		4%		5%		6%	
	Yellow.	Red.	Yellow.	Red.	Yellow.	Red.	Yellow.	Red.	Yellow.	Red.	Yellow.	Red.
As received through 100-mesh	44	4.4	38	3.8	30	3.0	21	2.1	16	1.6	14	1.4
Bolted through 200-mesh...	40	4.0	30	3.0	23	2.3	16	1.6	12	1.2	10	1.0

In making bleach tests it is desirable to know whether the sample under examination filters more rapidly or slowly than the standard sample. This has an important bearing on the amount of material which can be put through the filter presses in a given time.

The following data taken from my note books show the wide variations which occur between different Fuller's earths. The analyses were made chiefly for the purpose of determining the relation between the different mineral constituents. For that reason the results are scaled to 100, no account being taken of the organic matter which undoubtedly existed in most of these samples. They are instructive as showing the wide variations which can take place in iron and alumina and still apparently make no difference in the bleaching value of the earth.

Samples Nos. 1, 3, 4, 5 and 6 were all good bleachers, while sample No. 7 was only a fair bleacher. No 6 gave the best sort of results with cotton-seed oils, while No. 7 gives good results with mineral oils and is a type of earth which is subject to spontaneous combustion with oxidizable oils. These last two analyses, Nos. 6 and 7, were furnished the writer some years ago by the Owl Cigar Co., who mine the deposits at Quincy, Fla.

ANALYSES OF VARIOUS FULLER'S EARTHS

	No. 1. English Fuller's Earth, Marked S. L.	No. 2. English Fuller's Earth, Marked C. L.	No. 3. Duck Hill, Miss. No. 1.	No. 4. Duck Hill, Miss. No. 2.	No. 5. Grenada, Miss.	No. 6. X. L. Fuller's Earth.	No. 7. Quincy, Fla.
SiO_2	64.00	64.50	78.00	78.35	74.15	65.60	63.90
Al_2O_3	17.46	15.02	13.18	14.50	16.86	13.12	27.80
Fe_2O_3	11.40	12.80	7.35	6.30	5.82	12.83	3.46
CaO	3.05	3.46	1.57	.85	.36	6.58	2.42
MgO	4.09	3.86	trace	.....	1.51	1.64	2.42
NaCl	.....	.20	.....	.....	.....	.....	.....
	100.00	99.84*	100.10				
H_2O at 100°	12.05	13.85	8.50	9.22	.....	24.	17.40
Total H_2O	18.96	20.90	16.23	16.44	27.77		

* No. 2 when shaken up with water showed an alkaline reaction equivalent to .71 per cent Na_2O. The earth was alkaline to phenolphthalein, and as the writer remembers, was not a good bleacher.

There is one very important point, however, to be taken into consideration in the use of the material, and that is water of constitution. If a Fuller's earth be heated to absolute dryness so as to drive off the 10 to 14 per cent water of constitution, it becomes useless for bleaching vegetable oils, although it is believed that certain earths used for petroleum oils work better when absolutely dry.

The reason why Fuller's earth seems to bleach is not positively known. The facts, as nearly as we can ascertain, are that the bleaching by Fuller's earth seems to depend on the physical condition and to be closely allied to the proper amount of hydration of the complex silicate. Most Fuller's earth is very absorbent in its nature, but this property varies greatly in different samples. It is easily demonstrated by experiment that Fuller's earth containing an excess of moisture will not bleach vegetable oils, while, as mentioned above, it will not do to deprive the earth fully of this important constituent. For this reason, when Fuller's earth is added to oil at a temperature very much above 100° C., the water of constitution is driven from the earth, which becomes inert so far as combining with coloring matter is concerned. On the other hand, if Fuller's earth is added to wet oil the coloring matter has a greater attraction for the oil than for the earth, and consequently the oil is not bleached.

Fuller's earths differ greatly in their absorptive properties and show great differences in their liability to spontaneous combustion when soaked with oil. Certain Florida earths, when used with cotton-seed oil in the filter press, are very dangerous. The writer has observed cases where the application of air pressure after filtration to blow out the residual oil caused the contents of the press to ignite in a very few minutes. The only possible way of using such earth was to blow steam through the press to drive out the surplus oil and then remove the hot earth still containing 10 to 15 per cent of oil from the house as soon as possible. Great care was needed to see that the work was done without delay, as the earth would begin to smoke by the time it was dumped 100 yards distant.

Arrangement of Filter Plant. There are a number of details in the design of a bleaching plant which have much to do with its successful operation.

First, the filter presses should be sufficiently elevated above the bleaching kettles to permit the oil to flow back to the kettles, or to storage tanks, as the case may be. A convenient arrangement is to place the filters in a small house built on the roof of the refinery and have the tops of the bleaching kettles extend about $3\frac{1}{2}$ feet above the floor below. The advantage of this arrangement is that the filters can be steamed without being a nuisance in the refinery proper, and in case of fire there is little danger of damage to the rest of the building.

A convenient style of kettle is a cylinder 8 feet in diameter by 12 feet high with conical bottom. Pitch of cone 12 inches is ample. Four hundred feet of two-inch coiled pipe gives ample heating surface. Any convenient form of revolving agitator can be used. Fan or propeller blades near the bottom work well.

In addition to the mechanical agitator, the kettles should be provided with perforated air pipes, to be used in case the power should suddenly fail, or moisture be present in the fat.

Filters can be of any size, but 30-inch plates with $\frac{3}{4}$-inch recess, center feed, and 60 to the press, prove very satisfactory. The proper piping of the press is a matter of great importance. The oil feed line just before entering the press should be provided with a cross, or tee, into which should be connected air and steam pipes provided with first-class valves and check valves.

The steam pipe should be provided with a bleeder to carry off condensation.

For removing the oil from the press, instead of the usual trough and pipe connections, it is preferable to have at the feed end of the press a cast-iron box about a foot square with three transverse partitions. From the bottom of the sections, pipe lines are run back to the bleach tanks, to storage and the steam oil tanks. A light movable galvanized iron trough carries the oil from the filter cocks to this box. By slipping the trough a little from one section to another the oil can be sent wherever desired without the need of cocks or valves.

The filter pump should be slow moving, single acting, long stroke, type designed to pump against 150 pounds pressure. Such pumps wear much better than duplex. The pump should be located near the bleaching kettles and controlled by a steam valve near the filters. The suction line should be provided with plugged tees instead of elbows to allow easy cleaning in case of stoppage. The discharge should have a branch back to the bleach kettle. This enables the pump to be used for a transfer pump and at times is useful to help the mixing of the earth, by pumping from the bottom and discharging to the top of the bleach tanks.

The operation is quite simple. The oil is heated to the proper temperature, tested for moisture, and the Fuller's earth added. Agitation is carried on for 10 or 15 minutes. Then the oil is started through the press and run back to the bleach tank till a sample taken shows it is quite up to the standard, when the trough is moved so as to send the oil to storage.

When all the oil has gone through the press, air is turned in for 15 or 20 minutes to force out as much oil as possible. The trough is then moved to discharge to the steam oil tank, and the press thoroughly steamed.

Good practice does not leave over ten per cent in the spent earth. The spent earth is most conveniently removed by dumping into a hopper under the press, whence a stream of water carries it through suitable piping to the dump.

PRINCIPLES OF SEWAGE DISPOSAL

By GEORGE C. WHIPPLE, Consulting Engineer, New York City

Read at the New York Meeting, December 9, 1910

WHEN any branch of science is advancing as rapidly as that of the purification of sewage it is prudent at times to lay aside matters of detail and consider general principles in order that distorted ideas may be corrected and the whole subject viewed in proper perspective. That is my apology for bringing to your attention matters that are elementary and perhaps trite. At the present time a strenuous campaign is being waged against the pollution of our streams, purification of sewage is being urged with increasing insistence, statutes clothing boards of health with mandatory powers have been enacted in some States and the whole subject is being actively discussed. On the other hand certain counter-propositions are coming to the front, namely: Is sewage purification being misunderstood? Is it receiving an emphasis not justified by its results so far as sanitation is concerned? In view of the straitened financial conditions of some of our cities and the need of improved sanitation in so many directions—purer water, cleaner streets, better ventilation of public places, safer milk supplies—is the cost of complete sewage purification disproportionately large? Is sewage purification a universal sanitary necessity or essentially a measure for minimizing nuisance? These and similar questions are perhaps not fit for categorical answer, as local conditions may obligate one answer in one place and another answer in another place; but they are questions well worth the asking, and it is important that the data for answering them wisely shall be ready at call.

Basic Principles. The basic principles underlying all methods of sewage disposal are to get rid of sewage:

1. Without danger to the public health.

2. With the least possible nuisance to the smallest number of people.

3. With the least damage to property.
4. At the smallest possible cost.

Sewage and the Public Health. Experience has shown that failure to remove human excrementitious matter from a community promptly is a menace to the public health. Privies and cesspools in a closely built-up area are no longer tolerated. Their existence gives opportunity for the spread of disease by insects and animals and by the pollution of local wells. Statistics show that their abolishment and the substitution of sewers has a marked effect in reducing the death rate. In spite of its shortcomings the water-carriage system of removing fecal matter and other wastes of household and factory is the readiest, cheapest and altogether the safest method now available. It is likely to be the prevailing practice for many years to come, though perhaps not permanently.

The old bugaboo of sewer gas that frightened our fathers before the days of bacteriology is no longer feared by sanitarians, although its influence still pervades the antique plumbing regulations in force in many places. It is indeed desirable to keep the air of sewers from mixing with the air we breathe—the debilitating influence of all impure air should be avoided—but the danger of anyone becoming infected with the germs of disease by breathing sewer air is ordinarily extremely small. The water-carriage system offers practically no danger to the public health during the transmission of sewage.

It is when sewage is discharged into some body of water that danger may arise. The extent of this danger depends upon the use that is made of the water into which it flows. If the sewage of a large town or city is discharged into a relatively small stream and the water of this stream is used at some lower point as a public water supply, serious trouble is sure to follow. If the amount of sewage is small and the stream is large, the danger is less and decreases as the dilution becomes greater, until finally it becomes very small indeed, although never perhaps entirely disappearing. The danger of infection also decreases as the time interval between the entrance of the sewage and the use of the water lengthens, a longer time offering greater opportunities for the natural death of pathogenic organisms in an environment unfavorable to them and for the action of certain natural processes of self-purification. Seasonal differences are also to be noted. Pollution is most to be feared during the winter, when the natural agencies of purification

are less active, when the viscosity of water is increased and sedimentation therefore less potent, when the interference of other organisms is less marked, when the disinfecting action of sunlight is less, and when the increased oxygen content of water, due to its lower temperature, is conducive to the longevity of the germs of typhoid fever. Possibly, also, a lower temperature produces certain cellular changes in the bacteria themselves, condensing the gelatinous sheaths surrounding them until they virtually become protecting membranes.

Sometimes the water that receives sewage is used for bathing, boating, for harvesting ice, etc. The salt and brackish waters near our coast cities may flow over oyster beds or may be used for the pernicious practice of "floating" oysters. The waters of bathing beaches are not infrequently polluted with sewage. These are of minor hygienic importance when compared with the pollution of water supplies, yet none the less do they deserve serious consideration. The guiding principle should be that use of the water as well as the relative magnitude of the pollution determines its danger.

Purification of Sewage from a Hygienic Standpoint. It is possible to purify sewage so as to make it entirely innocuous, but to do this is so difficult, so expensive, and requires such constant and painstaking care that it is seldom attempted and still less seldom accomplished. In other words, it is not feasible to transform sewage on a large scale into a liquid fit for drinking.

The danger of sewage lies chiefly in the bacteria that it contains. These may be present as individuals scattered through the liquid or as clumps imbedded in masses of fecal matter and other substances, varying in size from microscopic particles up to lumps that can be seen with the eye. It is possible to kill the isolated individuals by the use of a disinfectant, but it is very difficult to kill bacteria embedded as described. The removal of the suspended matter mechanically and the disinfection of the isolated bacteria appears to be a logical and scientific method of treatment, but here again practice will find it hard to follow theory. For the process is one that requires greater care and more constant attention at the hands of the operatives than can be usually secured by the class of men employed at sewage-disposal plants.

The filtration of sewage, either raw or after some preliminary treatment, through sand beds at a low rate and with intermittent

application is altogether the most practicable method of removing bacteria from sewage. Where the conditions are favorable for the adoption of this process it is sometimes possible to remove on an average all but about 1 per cent of the bacteria. But it must be remembered that sewage often contains one million bacteria per cc. and that 1 per cent of this figure is 10,000 per cc., a number which far exceeds any allowable standard for drinking water. Furthermore there are always certain seasons of the year when the efficiency of even the best plant falls below this. It is not always that conditions are favorable for the adoption of this system. Suitable sand areas are not found in all parts of the country, and it is very rare that areas of sufficient size are found within reasonable distance of a large city.

The methods of sewage disposal that have come into vogue during the last ten or twenty years do not efficiently remove the bacteria from sewage. This is no disparagement to these methods, for they are not primarily intended to do so. Plain sedimentation and sedimentation assisted by the use of chemicals may remove many of the bacteria found in sewage, but a substantial proportion always remains in the effluent. The number of bacteria in the effluent from a septic tank is often greater than in the raw sewage entering it, and, while it is quite possible that on account of the lack of oxygen in the septic tank some pathogenic bacteria may be destroyed there, this cannot be depended upon, so that for all practical purposes the effluent of a septic tank must be considered nearly as dangerous to health as raw sewage. Contact beds and sprinkling filters may at times remove 80, 90, 95 per cent, or even 98 or 99 per cent of the bacteria, but in practical operation their effluents are found to contain bacteria in very large numbers.

It is only by combining these various processes that a substantial removal of bacteria can be obtained. In cases where it has been considered necessary to obtain the best possible effluent the process of purification has been carried on in several stages, viz., first, a partial removal of the suspended matter by screening or sedimentation or both; second, a process of oxidation, using sprinkling filters, contact beds or sand filtration; and third, a final removal of bacteria by sand filtration or disinfection.

Unfortunately the term "sewage purification" is popularly applied to any one or all of these processes. This has contributed

not a little to confusion of ideas. Laymen innocently suppose that when sewage is "purified" it becomes pure, whereas the sanitary engineer may mean only that it is less impure than it was before. How much less impure depends upon the method used. It would be of decided benefit to the cause of sanitation if instead of using the term "sewage purification" in a false sense, as we often do, we used more definite expressions, saying "sewage clarification" when we mean the removal of suspended matter, "oxidation" or "deodorization" when we mean the removal of putrescibility, and "sewage disinfection," "sewage filtration," etc. to describe the different parts of the process, leaving the term "sewage purification" to be used in a generic sense and understanding that it does not necessarily mean complete purification.

Danger from Storm Overflows. One of the most serious aspects of sewage purification from the sanitary standpoint arises from the common dual use of sewers. There are two distinct types of sewerage systems—the "separate system" and the "combined system." Sewers built on the separate system do not carry storm water, and the water that falls on roofs and yards and streets flows off in an independent system of drains, or, quite as often, dependence is placed upon surface drainage alone. Sewers built on the combined system are made large enough to carry the storm water as well as the dry-weather sewage. Local conditions govern in the choice of these two systems. The separate system is used chiefly in small cities where no supplementary storm-water drains are needed, where the sewage districts are small and the slopes rather steep, or where the sewage has to be pumped. The combined system is quite generally used in large cities, where the gutters cannot be overflowed without great inconvenience, where the percentage of impervious area is high, where the streets are crowded with pipes and conduits, where grades are flat and the sewer districts large, where pumping is not needed and where the sewage can be discharged with little or no treatment. It costs more to put in two sets of pipes, one for sanitary service and one for storm water, than for one system carrying both sewage and storm water. Experience, too, has shown that it is almost impossible to keep all storm water out of the sanitary sewers. Rain leaders become connected to house drains and even if a separate system starts out with stringent regulation, it is common for their enforcement to become

lax in course of time. In large cities especially this difficulty obtains. Then, too, there is the matter of ground water. If sewers are laid deep with reference to the water table, if the ground is porous and the sewer joints leaky (and they are never absolutely tight, even where that is the intention) the volume of ground water entering may be a large proportion of the total flow of sewage. This detracts from the advantages of the separate sewers.

The admission or non-admission of storm water to the sewers has an important bearing upon the purification of the sewage, influencing the size of the plant required and affecting its regularity of operation. In no city is the flow of sewage constant; in the natural course of events the maximum flow in separate sewers may be double the average flow, and minimum flow may fall to half the average. In the combined system every little rain increases the volume of sewage and severe storms multiply it many fold. Where there is a ready gravity outlet for the sewage, as for example in cities by the sea or on some large river, the district sewers are made of large size and discharge direct, but when the outfall sewer is long and the grade flat, or where the sewage has to be pumped, it is not practical to take all the storm water to the outfall. Under these conditions an intercepting sewer is built and storm overflows provided, the intercepting sewer being of capacity sufficient to carry the ordinary dry-weather flow and a certain small amount of the rainfall, with due allowance for ground water. Ordinary light rains may be thus taken care of, but there are usually many days in the year when, by reason of rains or melting snows, the capacity of the intercepting sewer is exceeded, and when the excess, mixed with some sewage, passes off through the overflows into some nearby water course. The amount of sewage spilled from intercepting sewers has rarely been carefully recorded, but calculations show that it may be from 2 to 5 per cent of the total sewage of a city for a year, while for short periods it may be a large proportion of the whole.

The storm water discharged at the points of overflow is diluted sewage. The first washings of the streets are often quite as rich in organic matter as sewage itself, while the increased velocity in the sewers at times of storm may carry along sediment that has been deposited on flat grades in the sewers during periods of low flow. Intercepting sewers overflow most frequently during the winter and spring months, that is, during the time when the

temperature of the water is low and when the germs of water-borne disease are most readily transmitted.

It is clear, therefore, that so far as the protection of water supplies from pollution is concerned, dependence ought not to be placed upon sewage purification works alone unless more than ordinary precautions are taken. For in small cities where the separate system can be used and all the sewage treated, reliable operation of the plant cannot be obtained unless extraordinary measures are adopted, while in the large cities, where separate systems are inapplicable, the overflow of intercepting sewers and the discharge of untreated storm water mixed with sewage will result in the pollution of the stream, even though the dry weather sewage be purified ever so efficiently.

Water Filtration a Safe Method of Protecting against Sewage Pollution. Long experience in this country and a much longer experience in England and Germany has demonstrated clearly and unmistakably that polluted waters can be and are being constantly purified by means of filtration to such an extent that they are reliably wholesome. In Germany the typhoid fever death rates in the large cities have been reduced to figures far below those of American cities. It is not at all uncommon for the typhoid death-rate to remain less than ten per 100,000 for ten and even twenty years in succession, the rate not infrequently dropping as low as three and four per 100,000. There the filtration of surface water is required by law and the efficiency of the filters is likewise required to rise to a certain fixed standard. It is worth remembering also that the streams of Germany are far from being unpolluted with sewage and that no general attempt is made to provide sewage purification works of high bacterial efficiency. Only in case of actual epidemics is the practice of disinfection of sewage followed. The theory that water filtration is superior to sewage purification as a means of protecting water supplies against infection appears to prevail. The success of this policy has been amply demonstrated.

If time permitted it would be possible to cite many concrete examples of the beneficial effect of the introduction of water filters in reducing the typhoid fever death-rate in American cities. Sedgwick, Hazen and others have shown that other diseases than typhoid fever are also reduced by the substitution of a pure water supply for an impure water.

Sewage Disposal as a Factor of Safety. On the other hand it must not be forgotton that water filters sometimes fail. Sometimes the method employed is not suitable to the conditions; sometimes the filters do not receive the careful operation that is necessary for them to do their proper work. Sand filters and mechanical filters properly operated can be depended upon to remove bacteria from water considerably polluted with sewage and render it safe and wholesome, and the use of bleaching powder or some similar disinfectant in connection with filtration further enhances safety, yet it is obvious that if the pollution is decreased the "load" on the filter is lessened and the danger arising from possible accident or from careless operation is reduced. The purification of sewage, therefore, even though it be incomplete, is of advantage, as it offers a second line of defense, an increased factor of safety. The writer believes that so far as the protection of water supplies is concerned sewage purification should be regarded from this standpoint, and the need of such a factor of safety balanced against the degree of purification of sewage demanded in each particular case.

Nuisances Caused by Sewage Pollution. Aside from questions that affect the public health directly the discharge of sewage into lakes and streams often gives rise to nuisances, the importance of which depends upon the character and intensity of the pollution, the natural agencies of purification and the use that is made of the water into which the sewage is discharged. These nuisances are chiefly those of sight and smell. The discharge of a large quantity of sewage into a small stream may make the water turbid and discolored, a sleek or scum may form upon the surface, deposits of sediment may form on the bottom and bubbles of gas may rise in the water, due to the putrefaction of such sludge. In extreme cases there may be offensive odors. Nuisances of this character are of real importance to a community and their importance increases in proportion to the numbers of people that are affected by them. Where a polluted stream flows through an uninhabited country no practical injury may result, as there is no one to be injured, yet the same conditions in a stream flowing through the heart of a city might be intolerable. Use, therefore, must be regarded as an element in considering the magnitude of nuisance.

The discharge of sewage into a body of water may also materially reduce the amount of oxygen present and if the amount of

sewage is large in comparison with the stream flow it may cause it to disappear altogether, producing an anaerobic condition with putrefaction of the organic matter. This condition is prejudicial to aquatic life. Few fish can live in waters in which the oxygen is reduced to less than half of that normally present, while some sensitive fish will shun waters in which the deficiency of oxygen is even less than this.

Nuisances Caused by Trade Wastes. It not infrequently happens that the greatest nuisance in streams is due not so much to domestic sewage as to the presence of trade wastes that may be discharged into the stream directly or that may be allowed to flow into the stream through the sewers. For example: The discharge of spent dye liquors may color the water of a stream for many miles; petroleum wastes from gas works may cause iridescent films to form upon the surface of the water, producing an unsightly appearance and increasing the odor directly as well as indirectly by excluding air from the water; the acid iron wastes from galvanizing works may cause a rusty discoloration that not only imparts a brown color to the water, but paints the rocks and submerged stumps, etc., along the shores for many miles. When nuisances of this character arise it is wise and proper to install sewage clarification plants and sometimes more elaborate works, for such nuisances cause real damage to property and to personal comfort. Trade waste pollution may interfere with the filtration of water even more than sewage itself. Illustrations of this are the paper mill pollutions in New York State and the acid iron wastes in Pennsylvania.

Purification Plants as Nuisances. Purification works themselves may be a source of nuisance. There is a natural opprobrium attached to a region where such works exist that results in a recognized deterioration of property values. The processes used for the purification of sewage not infrequently result in odors that may be distributed over considerable areas. Where the purification works are entirely covered, as some kinds of works may be, little or no nuisance may result, but where for example the sewage is first submitted to putrefaction in a septic tank and the septic effluent then sprayed into open air upon the surface of sprinkling filters, this exposure of the atomized liquid results in the liberation of odors that may reach distances of half a mile from the plant, depending upon the amount and character of sewage treated,

the local topography, prevailing direction of the wind, humidity in the atmosphere and other conditions.

Frequently high winds will carry the spray itself for several hundred feet with inevitable bacterial pollution of the air. In the operation of sprinkling filters also it has been found that at certain seasons of the year swarms of flies breed in the porous beds. These are very troublesome in the immediate vicinity of such works. In considering the need of sewage purification it is proper to balance these possible nuisances against those resulting from the discharge of unpurified sewage into a body of water. It not infrequently happens that the installation of sewage purification works merely substitutes one nuisance for another.

Elimination of Nuisances by the Purification of Sewage. Experience has shown that it is practicable to purify sewage to such an extent as to prevent it from being a cause of nuisance. By submitting it to one or more of the many processes that have been devised it is possible to remove the greater part of the suspended matter and to so change the organic ingredients that they become no longer putrescible or odoriferous. The processes employed have varied considerably from time to time and in different places. Where large areas of land are available the method of broad irrigation has been used with success. Where the soil is sandy and intermittent filters can be constructed cheaply this method has found favor. Where the soil is heavy it has been found necessary to use coarse material and sprinkling filters and contact beds have come into vogue. Screens, settling tanks, chemical precipitation tanks, septic tanks and the recently devised clarification tanks are largely used, sometimes alone and sometimes in combination with other processes. The choice of method is one to be decided upon only after careful study of local conditions with reference to the best utilization of natural resources, the required efficiency and the cost of the plant both for construction and operation. In Germany clarification plants have been largely used. The art of screening has been developed there further than elsewhere, as well as the use of improved methods of removing suspended matter in sedimentation tanks of various kinds. In crowded England, where the streams are small and the pollution considerable, it has been found necessary to carry the process further and protect the dissolved oxygen in the streams. Thus sprinkling filters and contact beds have been widely used. Land

treatment in England has been less successful on account of the clayey nature of the soil. In the course of time practice in the United States doubtless will become similarly differentiated.

The objections raised in regard to sewage purification plants when considered from a sanitary standpoint lose their sinister character when these plants are considered from the standpoint of elimination of nuisance. For example, the overflow of sewage from an intercepting sewer may be objectionable as far as bacterial pollution of a river is concerned, yet it may cause no nuisance to sight or smell, for the reason that at the time when the sewers overflow the streams also are likely to be in flood, so that the dilution of the sewage is increased. Thus considered it would not be necessary at such times to purify the entire sewage of the city even if it were possible. It has been proposed even to utilize the seasons of flood for discharging the sludge accumulated during dry weather. The Columbus plant was designed with this idea.

Fundamental Processes in Sewage Purification. The fundamental processes in sewage purification are:

1. Separation of the suspended matter from the liquid sewage.
2. Destruction of the putrescible organic matter in the liquid sewage, looking to final mineralization, by the processes of oxidation and bacterial action.
3. The transformation of the sewage sludge to a condition of stability and inertness by bacterial action, with or without oxidation.
4. Destruction or removal of the bacteria from the liquid effluent.

These processes are by no means clear cut. They overlap at many points. To begin with there is no sharp line between dissolved and suspended matter, a considerable proportion of the sewage solids being present as colloids, that is, particles that are exceedingly minute.

The preliminary processes of purification include the use of such devices as screens, sedimentation tanks and coarse filters. Screens are sometimes coarse, sometimes fine. Sedimentation tanks vary all the way from grit chambers, through which the sewage flows rapidly, allowing only the heavy particles to settle, to septic tanks in which the time interval is so long that the sewage becomes anaerobic, with the resulting liquefaction of part of the sludge.

Chemicals are sometimes used in connection with sedimentation to assist the process.

In order for oxidation and bacterial action to occur to the best advantage it is necessary that oxygen be brought into intimate contact with the sewage. In the sprinkling filter this is secured by spraying the sewage continuously into the air, letting the drops fall upon beds of coarse material through which they trickle downward, spreading out over the inner surfaces and depositing there more or less suspended and colloidal matter. Free ventilation of these beds is necessary. Oxygen thus comes in intimate contact with the particles of sewage and bacteria develop on the surfaces of the stones, coke, slag or other material composing the filter. If the process is properly carried on the organic matter becomes almost non-putrescible and progress is made toward its mineralization. The colloids are also removed to a considerable extent. A large proportion, 85 to 95 per cent, of the sewage bacteria is incidentally removed.

In contact beds a similar but modified action occurs. Here the process is not continuous, but intermittent. The sewage is not sprayed over the beds, but flows in at the top or bottom until the bed is full. Then it stands for a time, during which sedimentation occurs and all the oxygen is very likely used up. Finally the liquid is drawn off and the bed allowed to remain empty. During the rest period and part of the time when standing full opportunity is given for the oxidation of organic matter. The contact bed is less efficient as an oxidizing agent than the sprinkling filter. It occupies an intermittent position between a settling basin and an oxidizing bed. On account of the sedimentation that occurs the beds become choked after a time, so that the material has to be removed and cleaned, thus differing from the sprinkling filter, which may operate for a number of years without cleaning.

Intermittent sand filters serve the double purpose of removing suspended matter and oxidizing the organic matter. They are extremely efficient in doing both. By reason of the finer sand used the exposed surface of the filter is enormously greater than that of the sprinkling filter. This, combined with the slow rate at which the sewage passes through it, makes a far more intimate contact between the oxygen of the air and the sewage and offers greater opportunities for bacterial action. Intermittency is essential to the processes in order to allow the oxygen to penetrate

into the pores of the filter. The finer material also acts as a strainer to remove substantially all of the suspended matter, retaining most of it on the surface and only very slowly becoming clogged beneath. The economic difficulty with this process is usually the lack of suitable areas of land of proper character.

The proper disposal of sewage sludge is perhaps the most difficult part of any purification process. At present there is no satisfactory method of destroying it by oxidation without nuisance or without great cost. To allow fresh sludge to be exposed to the air results in offensive conditions. The artificial aeration of tanks containing sludge has not proved a practical success. Fortunately, however, sludge may be changed to relatively stable organic matter by allowing it to putrefy anaerobically, and if this is done in a closed chamber little or no nuisance will occur.

The septic tank was intended to perform this service, and it was thought that the sludge would not only be changed in character, but in great measure destroyed. This is to some extent the case, but the extravagant claims for the septic tank have not been substantiated in practice. In the septic tank the improvement in the character of the sludge is carried on at the expense of the quality of the liquid effluent, for the anaerobic operations are conducted in the chamber through which the liquid sewage flows.

The use of the septic tank stimulated the interest in the anaerobic decomposition of sludge, and as a result Travis in England, Dunbar and Imhoff in Germany, and others, have devised special tanks in which the sludge alone remains septic. Hazen also used this idea in his suggested plans for the purification of the sewage of Paterson, N. J., in 1906.

Degree of Purification Required. Viewing the subject of sewage disposal from the double standpoint of preventing nuisance and furnishing a second line of defense to water purification works, it is logical to base the completeness of the process needed in any case upon the nature of the body of water into which the effluent is to be discharged and to take into account the natural agencies of purification that may exist in the water. To ignore the use of such agencies would be a waste of natural resources directly opposed to the present cry of conservation. The water of lakes and streams contains a considerable amount of dissolved oxygen, this amount varying according to temperature and being in this climate about

twice as great in the winter as in the summer. Sea water dissolves somewhat less oxygen than fresh water. This dissolved oxygen is available for purposes of oxidation. Some waters also contain nitrates from which the oxygen may be utilized under the influence of the action of certain bacteria. When sewage is discharged into water containing oxygen its organic matter becomes oxidized in time, and if the amount of sewage is not too great the oxidation will become complete and no nuisance will result.

In order that the dissolved oxygen may be used to its best advantage it is necessary to have the sewage thoroughly and quickly diffused through the water. Otherwise the oxygen near the point of discharge may be too greatly reduced and nuisance may result, even though there be plenty of unused oxygen near by. The extent to which the oxygen in the water of a stream may be safely reduced is a matter that demands more study than has yet been given to it. Experience has shown that putrefaction will seldom occur if the sewage of a thousand people is discharged into a stream which has a flow of more than about 4 cubic feet per second. Other conditions than the volume of flow enter into the problem, an important one being the velocity of the stream and the nature of the bed. The flow of water over waterfalls and dams and through rapids increases the amount of oxygen that may be taken up from the air and thus increases the capacity of the stream to receive sewage. In the case of lakes dilution is governed largely by the effect of wind in producing circulation of the water. In the case of harbors it is governed by the tidal flow. Cities located upon large streams, the Great Lakes, or the ocean have at their command ample resources for the oxidation of sewage, and where such natural resources exist it is unnecessary to resort to oxidation by artificial processes.

On the other hand cases may exist where the important need is to maintain the oxygen conditions in the water into which the sewage is discharged, the necessity of keeping out suspended matter being of minor importance. In other cases, and quite frequently in the interior of the country, both the removal of the suspended matter and the oxidation of the sewage may be required.

Co-operative Sanitation. What appears to be needed in this country at the present time is some method of co-operation by which needed sanitary reforms can be brought about at least expense. It is unbusinesslike to compel the purification of the

sewage of a large upstream city in order to protect the water supply of a small city lower down, provided pure water can be furnished the latter in some better and cheaper way. Legislation that clothes the State authorities with power to prevent the pollution of sewage, but does not give them power to compel the purification of water or to control pollution by trade wastes is unfortunate. It naturally leads to litigation rather than co-operation, and may retard rather than hasten necessary sanitary reforms. If our State authorities cannot be trusted in this matter it may be that a proper solution of the difficulty will be found in the establishment of District Boards similar to those in England and Germany, such Boards having jurisdiction over the limits of particular watersheds. In some respects these natural hydrographic boundaries have advantages over artificial State boundaries. In the near future also our national government will doubtless take a hand in the matter. In whatever form the authority may be constituted the idea of co-operation should prevail and ironclad rules against stream pollution should give way to a rational distribution of the burden of purification of both water and sewage, and an equitable adjustment of cost made between the parties interested, thus decreasing the total expense of sanitary measures required, and utilizing natural resources for the purification of sewage in water as far as this is safe.

If the system of water carriage of sewage continues in use, the time will some day come when the sewage of all of our cities will be purified, partially or completely, and all surface water supplies filtered. It is proper to anticipate this consummation as far as our means permit, but meantime it is good business and sound common sense to spend our money first where it will go furthest and do the most good, building water filters and sewage purification works, sometimes one, sometimes both, as they may be needed.

Adequate remedies against stream pollution from the standpoint of nuisance have been usually obtained by an appeal to the principles of common law. Cases involving bacterial pollution by sewage have been thus far too few to establish definite precedents. It will be interesting to see whether, in view of our increasing population, and especially the increasing growth of our cities, the courts will ultimately decide that the use of unfiltered river water as a source of water supply by riparian owners is a reasonable use of the water.

The writer is optimistic in regard to the improvements that are being made in methods of sewage disposal. He believes that the near future is to see extensive developments in the art. Important as are the recent improvements in the technical details, still more important and necessary is a rational assignment of the means employed to the work at hand. The use that is to be made of the water into which sewage is discharged, and the conditions tending to natural purification are to be studied with greater minuteness than ever before; the method of dilution is to be used more rationally; and the designs of the sewage-disposal plants made to fit more closely the particular conditions. The general result will be the construction of more but often simpler plants for the treatment of sewage, and, where occasion makes necessary, the installation of devices for bacterial purification more efficient than those now employed.

SEWAGE DISPOSAL IN EUROPE

By RUDOLPH HERING, C.E., D.Sc.

Read at New York Meeting, December 9, 1910

THE brevity of time allowed for so large a topic necessitates the selection of only a few subjects that may be of most interest at present.

England, because of the relatively small size of her rivers and the rapid growth of her cities during the middle of the last century, started the improved methods of sewage disposal now pretty generally followed. Other European countries followed, but here and there proceeded along somewhat different lines. A study of characteristic European works is therefore always both interesting and instructive.

The first subject which I shall take up is the disposal of sewage by dilution in large bodies of flowing water.

It has always been observed that sewage when sufficiently diluted could be discharged into rivers without danger of creating any nuisance. On account of its economy, this disposal has been practiced with preference wherever possible. When, however, it was discovered that certain diseases were caused by sewage and water-borne germs, a reaction set in, and it was endeavored first to purify the sewage on land to a degree that made the effluent harmless. The success of sewage purification works, however, was largely either disappointing in efficiency or in cost, or the works were limited to processes which could not everywhere be used, or to localities where the advantages were exceptional.

Of the sixteen largest cities in the world, having a population of over one million inhabitants, every one without exception now employs the dilution method, where flowing water is available and a sufficient quantity of oxygen is dissolved in it, to represent a flow of fresh water equivalent to at least 3 cu.ft. per second for every thousand persons discharging sewage. The only cases where

such a flow is not available are London, Paris and Berlin, because their rivers are too small. But even those rivers receive enough decomposing organic matter to keep the dissolved oxygen at the lowest practicable figure.

Where a water supply is taken from a river, it must be purified even after any sewage entering above has been treated, because:

1. The methods most likely to remove pathogenic bacteria from sewage, such as intermittent sand filtration, are not frequently available, and the least expensive methods of treatment do not generally assure a destruction of the bacteria.

2. The rain-water washings from habitations and the manure from fields, etc., can bring pathogenic organisms into the rivers.

3. The traffic upon the rivers and along their shores is also liable to permit disease germs to enter them.

Where no water supply can be taken, as for instance, in New York harbor, we have the farther possibilities of infecting food fish, oysters, etc., even if the city's sewage were purified, because:

1. Where rain water enters a city's sewers and thoroughly mixes with the sewage, the overflows into the rivers during storms carry disease germs into them. While this would not occur continuously, still it occurs during every rain. The danger is only lessened, but not removed. When sewage is separately removed and does not reach the river, then we still have the entire surface washings from every rain, including the dust and manure, to enter the river.

2. As the ships after they enter a harbor are cleaned up, have their sewage tanks emptied, etc., we have another large and, as evidenced by several cholera epidemics, serious source of infection.

When we compute the commercial value of food fish, oysters, etc., we find it insignificant compared with the cost of removing all of the conditions that would impair their hygienic qualities, if taken near a harbor. It will therefore be much cheaper to take them instead, at a greater distance from large cities and where no dangers exist.

With these conclusions regarding the infection of water supplies and food fish, we have now to consider the only other aspect of sewage disposal by dilution, namely, the prevention of a nuisance. This nuisance can be either to sight or smell.

A nuisance to sight is prevented almost everywhere in Europe

by screening and by otherwise keeping from the surface all plainly visible floating matter, which is usually the most objectionable part of the sewage. It suggests its origin and defiles the appearance of the water surface for quite a distance.

In Germany screening has been further developed than elsewhere to avoid this trouble, and we find screens with a mesh as small as one millimeter. In Hamburg the screens have one centimeter space between the bars. Along the larger rivers screening is usually the only method of purification found necessary.

A nuisance to smell is obviated by:

1. An endeavor to so build the sewers that their smooth interior surface and good grades will deliver the sewage practically fresh to the outfall. This result is obtained, wherever these conditions exist, in numerous communities of both Europe and America.

2. An immediate submergence of the sewage as far below the surface of the river or other body of water as practicable, and by the sufficiency of this water to oxidize the sewage, which prevents even the slightest odor from arising.

The river Elbe near its mouth is a fresh-water stream supplying with water both Hamburg and Altona, having a population of about 900,000 persons, and it receives also the raw and fresh sewage of both of the cities. The only preparatory treatment is a small grit chamber to keep out sand and gravel, and a screen to keep out the larger suspended matter. The sewage is dispersed at a number of points several hundred feet from shore and about 30 feet below the surface. The sewage never becomes visible or odorous. There is more shipping per square mile in the harbor of Hamburg than in any other harbor except London. The oxygen dissolved is about 50 per cent of saturation. The tidal range is about 6 feet. The appearance of the water is like that of the Delaware river at Philadelphia, Pa. Below the city are bathing pavilions, boating and first-class restaurants. The reasons for this favorable condition are simply screening, a discharge well below the water surface, and a dispersion into a sufficient quantity of diluting water.

Similar results may be seen in the river Maas at Rotterdam. The interior cities of the continent on the rivers Elbe and Rhine, such as Cologne, Wiesbaden, Dresden and Magdeburg, discharge their sewage, after grit settling and fine screening, into the rivers without being visible or causing any nuisance whatever.

London until hardly fifty years ago discharged her sewage into the Thames without objection. The growth of the city and the smallness of the river made it necessary later to effect a partial purification of the sewage before it entered the river. This is accomplished by precipitating most of the suspended matter as sludge, removing it and carrying it further down the river to its mouth in boats and dumping it. It is less expensive to precipitate

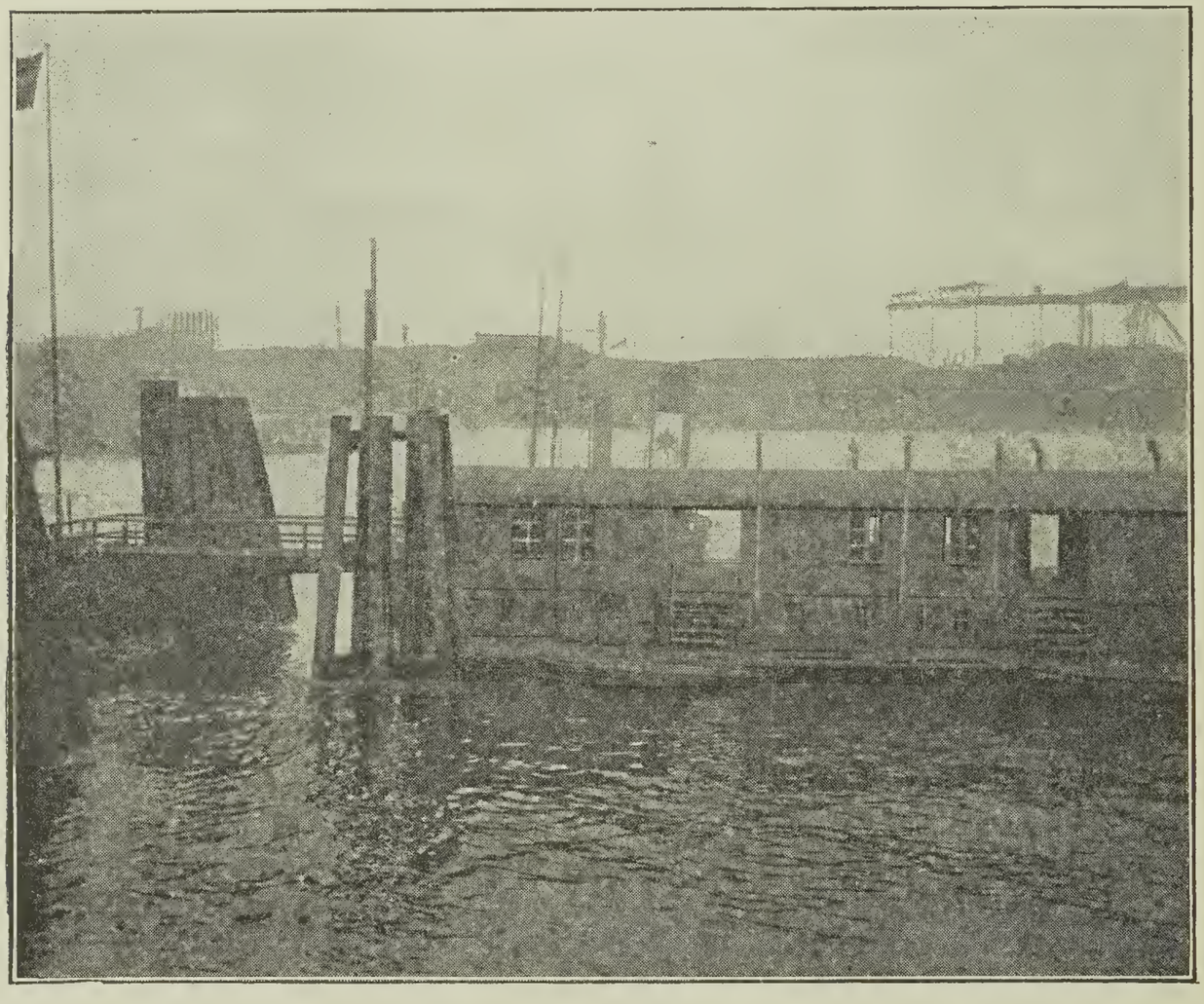


FIG. 1.—Location of Sewage Outfall at Hamburg, 30 feet below water surface, and showing width of river.

and artificially to convey the sludge to this point than to carry it down in sewers. The tidal range at London is 18 feet.

The amount of foul matter discharged into the Thames is limited by the amount of dissolved oxygen found in the water. The discharges and degree of treatment are so regulated that the saturation does not generally fall below 30 per cent, which leaves the river with its crowded shipping in an entirely satisfactory condition and wholly free from nuisance. Of late years the

saturation has been as low as 22.2 per cent without objectionable results.

The rapidity in the rate of oxygen absorbed by a river from the atmosphere is largely dependent on the rate of consumption by the myriads of bacteria and other microbes requiring it, which increase in number with the amount of organic matter in solution or suspension. It depends also upon the degree of disturbance of the water surface.

Dibden has given the amount of oxygen which can be absorbed from the air by the river Thames at the point where it is most polluted, at nearly one pound per thousand cubic feet of water per day, and where it is not polluted at about one pound per ten thousand cubic feet of water per day.

The Mersey and Irwell standard in England requires 400 cubic feet of dissolved oxygen per day to make the sewage of a thousand persons unobjectionable in a river. This volume is equivalent to about 35 pounds of oxygen. By using Dibden's standard for non-polluted water as above, we therefore require a flow of water of 350,000 cubic feet per day, or about 4 cubic feet per second per thousand persons, which is about equal to the dilution in the Chicago drainage canal.

In Liverpool and Birkenhead the crude sewage of about 800,000 persons is satisfactorily discharged into the river Mersey; in Bristol and Belfast the crude sewage of about 300,000 persons in each city is satisfactorily diluted. In Hull the crude sewage of 240,000 persons is diluted by the river Humber.

We have, therefore, ample experience the world over to justify the use of oxygen in flowing water for the purification of sewage, as much as the use of oxygen in the air at sewage disposal works on land, particularly as the chances for a nuisance are at once eliminated by immediate submergence in water, while the chances for a nuisance on land depend largely upon the human element operating the works. The preference between the two methods will naturally be based on local conditions.

The second subject which I shall take up relates to the purification of sewage on land.

It has always been supposed that any good system of purification on land was sufficient to destroy all disease bacteria. But we can no longer place entire confidence upon this early belief. Typhoid bacteria have been even cultured in sand filters when

sufficient dissolved nutriment, as furnished by sewage, was contained therein. Whether the coarse-grained filters, in which even a less amount of organic matter is removed, furnish otherwise better conditions for their extinction, is not yet known. If a protection against the escape of pathogenic bacteria from filters is desired, it is now known that a subsequent treatment with a hypochlorite solution will economically assure their destruction, as proposed on a large scale in Baltimore, Md.

It remains, therefore, to concern ourselves yet with the other objectionable element, namely, with the avoidance of nuisance.

It may again be said that also in the case of land disposal, sewage should be delivered as fresh as possible, not only to prevent bad odors arising from the sewers themselves, but because the most desirable processes of purification are benefited thereby. On the continent of Europe it is rare to find the sewage delivered from the sewers in a septic condition. Proper design, careful construction so as to have no retention, and sufficient flushing and cleaning, are the means to deliver the sewage fresh. The consequences of failure in the respect will be odors at the points of delivery and sometimes also throughout the works of purification.

Secondly, the sewage must be separated into two parts, the coarse solids and the liquids with the finely divided suspended matter. This separation is necessary, because the most efficient and least expensive treatments of each, are radically different. We have, therefore, at the outset to consider the best means of separation.

The heavy matters, which are chiefly sand and gravel, will readily deposit if the velocity of the passing sewage is reduced to less than 12 inches per second, but not less than 8 inches per second, because if it should be less, the fine organic matter also deposits and would form foul sludge. The gritty material does not become foul and can be used for various purposes.

The sewage relieved of this grit then passes onto what may be broad irrigation or intermittent sand filters, where it is given an oxidation and converted into water with any desired degree of purity. In the few available minutes, these older treatments will not be further mentioned, as the remaining time is required for the newer methods of oxidation in coarse-grained filters.

As these filters can purify only liquid sewage and very finely suspended matter, it is important that a separation be made from

the coarser suspensions which have passed the grit chamber and screen.

Some fifteen years ago it was thought that the septic tank would perform this task and at the same time obliterate the deposited suspended matter or sludge by putrefaction and liquefaction. But whatever slight advantages existed, there was the great

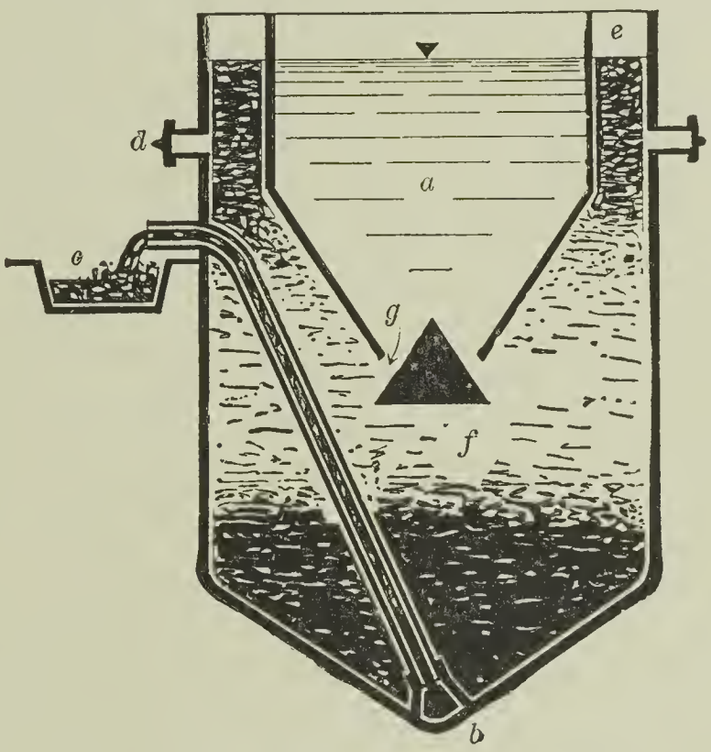


FIG. 2.—Diagrammatic Cross-section of Imhoff Tank.

a. Upper chamber for flowing sewage, to be retained about two hours in passing through.
b. Bottom of pipe receiving digested sludge.
c. Channel into which digested and inodorous sludge is discharged and removed to the drying beds.
d. Pipe for removing scum.
e. Shaft permitting escape of gases and accumulation of fatty particles or scum.
f. Lower chamber in which sludge decomposition takes place.
g. Slot through which settling particles enter the lower chamber and which prevents rising gas bubbles from bringing up particles of fouling matter into upper chamber.

disadvantage of the resulting very foul odor and the disappointment in getting a much smaller liquefaction than expected. There was a further disadvantage that the septic condition of the liquid made a subsequent oxidation somewhat slower and more difficult than if it had remained non-septic. The sludge itself was foul when removed and in most cases continued so for some time.

Dr. W. O. Travis in Hampton, England, first endeavored to

advance the problem by separating the septic tank into an upper and lower compartment, allowing the fresh sewage to enter the upper and to deposit its suspended matter through a slot into the lower one. Thus a substantial separation was made, but there prevailed an erroneous idea which he shared, that for the purpose of thoroughly digesting the sludge in the lower compartments, it was necessary to admit for passage at least a small amount of fresh sewage to supply the organisms for the septicization. The

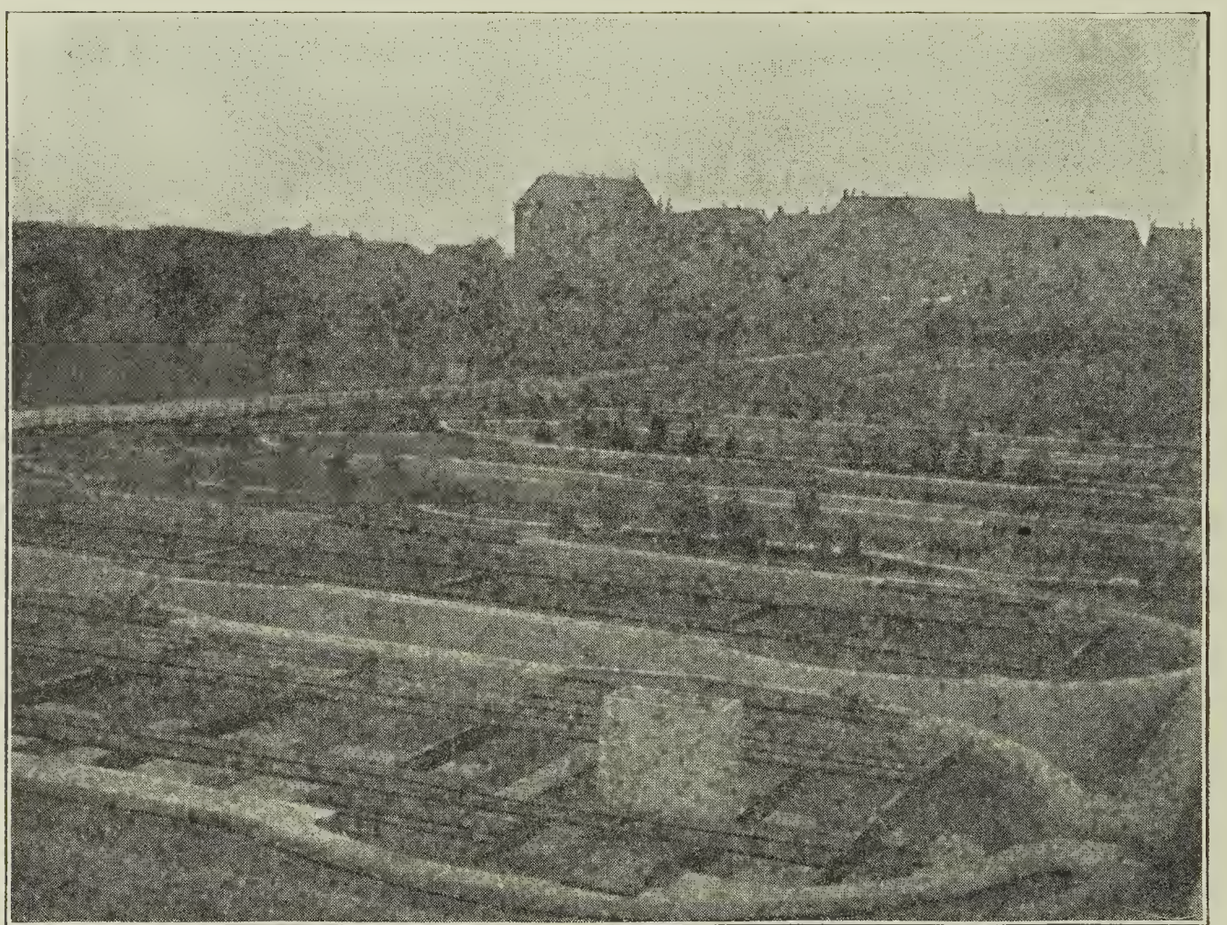


FIG. 3.—Imhoff Sewage Tanks at Bochum, Germany.
Note the buildings in the neighborhood.

proportions of flow through the upper and lower tanks were as 4 to 1. He further removed the sludge at too early a time, before it had lost the non-resistant organic matter by its rotting away. The results in these tanks are, therefore, both an effluent and sludge with a slight foul odor.

In experimenting with this tank in the Emscher district of Germany near the city of Essen, Dr. K. Imhoff found that several changes would permit the discharge of a fresher effluent and of an inodorous and well-digested sludge. The Imhoff tanks have now

been used for several years, fully confirming the original anticipations. In fact, in some instances, by a long ripening process they have rather improved their efficiency with age.

The essential changes consisted:

1. In arranging the slot through which the suspended matter subsides, so that no gas bubbles from the lower tank can rise into the upper and bring up foul suspended matter into the fresh sewage.

2. In allowing no circulation of sewage whatever through the lower tank.

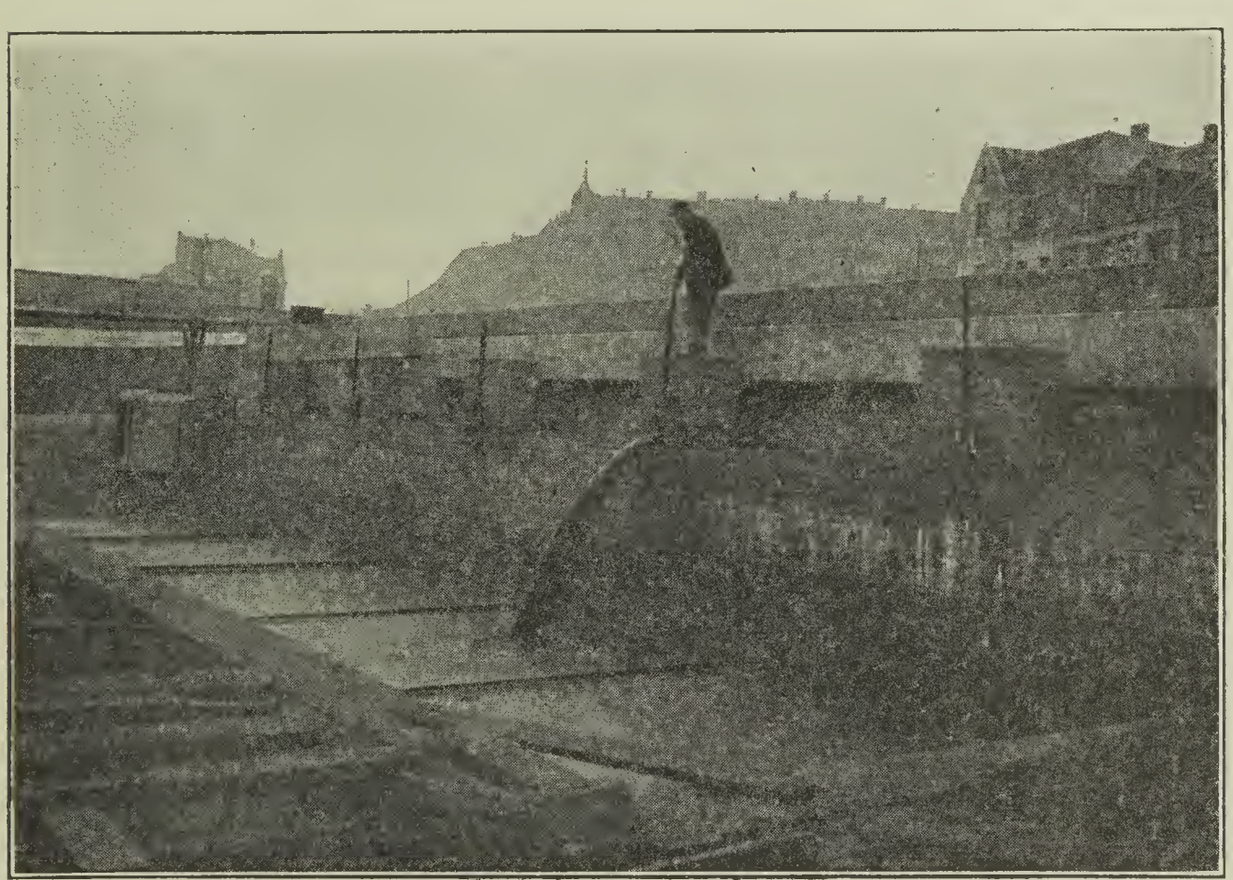


FIG. 4.—Withdrawal of Digested Inodorous Sludge from Imhoff Tanks at Essen, Germany.

3. In extending a part of the lower tank independently up to the surface to allow of the formation of a scum by the rising bubbles and for the escape of the gases of decomposition, which consist chiefly of methane and carbon dioxide. The escaping gases are, therefore, inodorous.

The reason why sulphureted hydrogen, the chief foul-smelling gas arising from sludge putrefaction, is practically eliminated in these tanks, is not yet explained. It seems that the practical exclusion of fresh sewage evidently allows of a gradual natural

selection and survival of those bacteria which produce the inodorous gases mentioned.

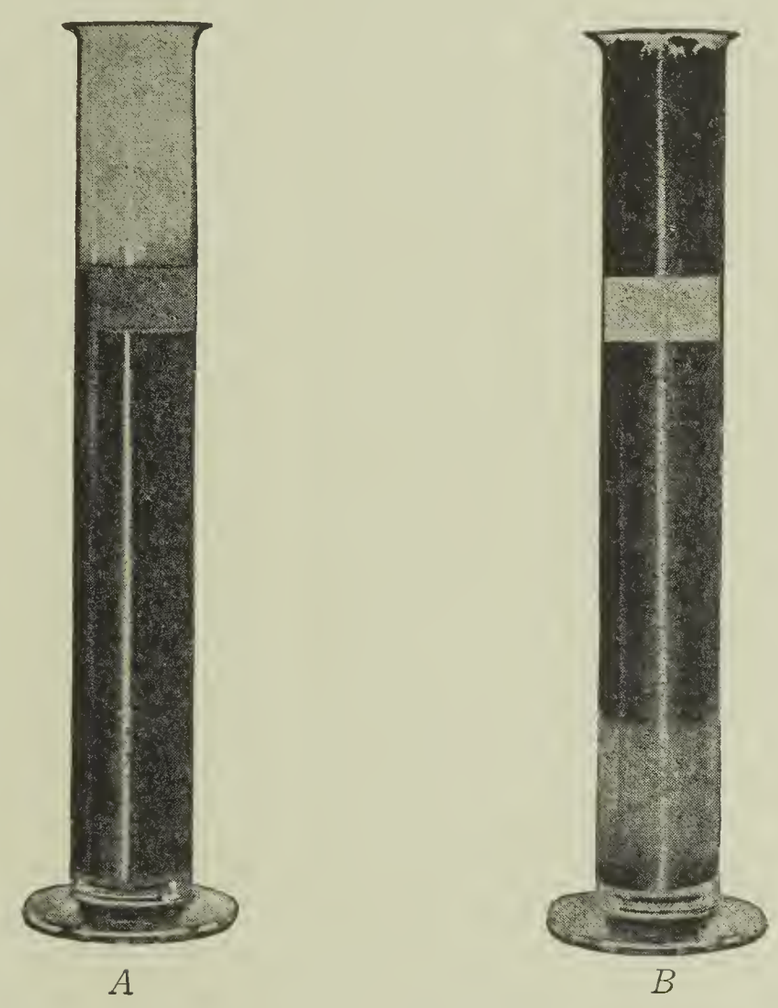
To complete the rotting away of the non-resistant matter in the sludge, it should remain in the tank from three to five months, according to local conditions. It is further quite important that the sludge particles should frequently change their position to avoid the accumulation of toxines. This change is produced by withdrawing at the bottom of the funnel-shaped tank, at intervals of once or twice a week, an amount of digested sludge equivalent to the solid matter which had meantime been deposited on the surface. The change is also produced by the continually rising bubbles of gas, due to the active decomposition which is thus encouraged.

The result is that the sludge has been changed from a slimy and sticky state at the top to a friable and crumbly state at the bottom, and from having a high to a low hygroscopic capacity by losing its finest particles. It contains 75 per cent of moisture when withdrawn, but can be dried within four to six days sufficiently for spading and removal. The sludge has an odor of garden mold, which at first is combined with a tarry odor, the reason for which is yet unknown. The appearance of the sludge after withdrawal from the lower chamber of the Imhoff tank is shown in Fig. 5. *A* and *B* are two glass cylinders. *A* shows sludge, with about 75 per cent of water just withdrawn from the lower chamber of an Imhoff tank. A strip of paper indicates the height of the sludge surface. The sludge had been under 10 meters pressure head. As it was withdrawn the pressure was removed so that the gas bubbles expanded and most of the gas escaped. While the sludge was under pressure it was heavier than water. Now, by expansion of the gas, it gradually increases its volume to such an extent that it becomes lighter than water and soon rises. (See *B*.)

B shows how after the rising of the sludge, a part of the contained water separates from it and drains to the bottom. The sludge then resembles a spongy mass floating upon its own water, and has risen above the level, indicated on photographs *A* and *B*, by a strip of paper. The photograph *B* was taken twelve hours after *A*. The sludge has now only 60 per cent of water. The drained out water below is not turbid but clear, and rapidly disappears in the underdrained beds upon which the sludge is discharged.

The contrast between septic sewage purification works with odors, perceptible sometimes a mile away, and the Emscher district works, surrounded by agreeable parking or by residences, where there is no offensive odor, is certainly striking.

A test of this process of sludge digestion was made in Philadelphia, Pa., lasting almost a year, and the same results were obtained.



A *B*

FIG. 5.—Illustration of the Changing of the Sludge after Withdrawal from the Lower Chamber of the Imhoff Tank.

It seems, therefore, that the annoying question of sewage sludge disposal, which has been prominent for at least a quarter of a century, has at last reached a satisfactory solution, for such cases where the Imhoff process is available.

Let us now quickly follow the liquid from which this sludge has been separated. The passage of this liquid through the sludge tanks generally takes about two hours.

In all cases of sewage oxidation on land, the first requirement is to spread the liquids and the fine so-called colloidal particles

suspended therein, as a thin film over the greatest practicable surface, so that the oxygen of the air and the lower forms of life can get the best opportunity for a contact with it. This surface is provided by the grains of earth, sand, gravel, or stone of which the purification beds are made.

The second condition is that the surface of the grains covered by the film of sewage must be inhabited by animal and vegetable organisms which, with their vital activities, transform by oxidation the decomposable sewage liquids and solids into inoffensive stable mineral compounds.

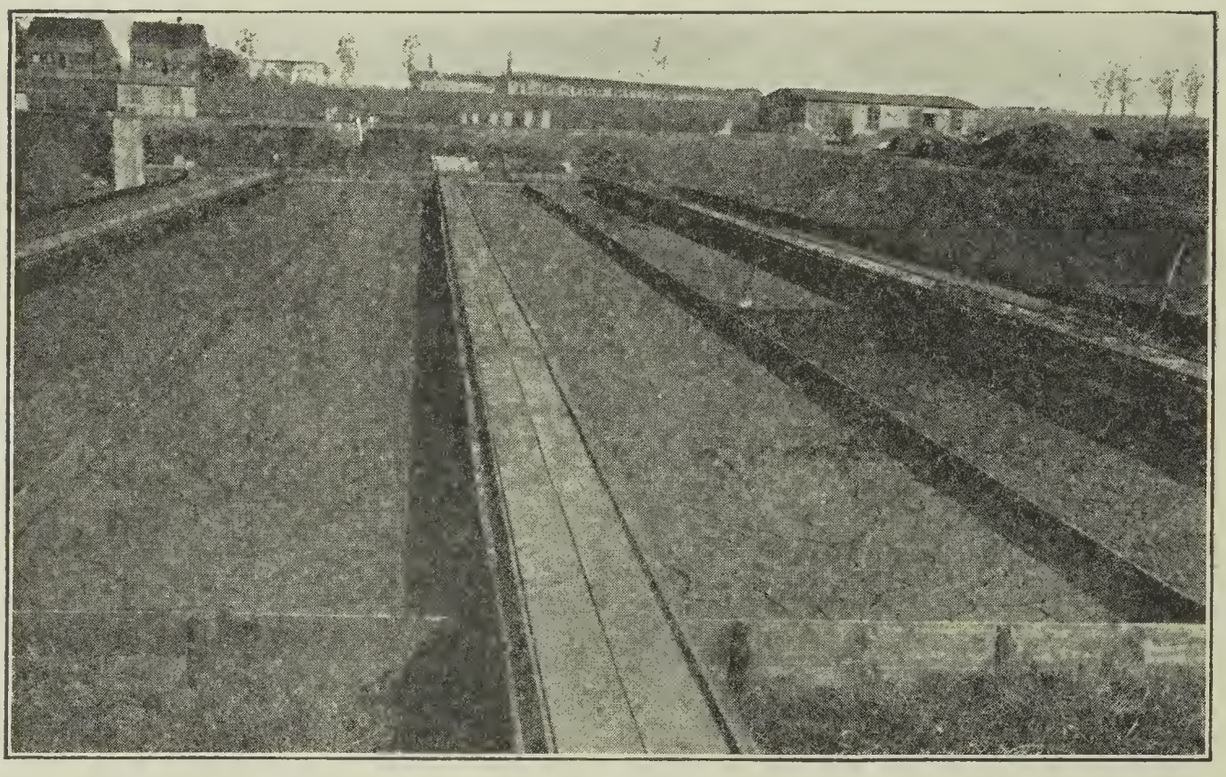


FIG. 6.—The Sludge Beds at Essen, N.W. Germany.
To the left the sludge is two days old, in the center three days, and to the right four days old, and is sufficiently dry to be spaded.

These organisms are brought to a large extent by the sewage itself and are multiplied within the filters. A few months of favorable conditions may be required before a filter has become thoroughly filled with the required species, in short, before it is ripe.

The third condition is that an opportunity must exist to force the activity of the organisms to the greatest practicable extent consistent with the available nutriment. The most important means for this purpose is an abundance of fresh air in contact with the entire sewage film at all times, because the organisms must be

freely furnished with all the oxygen they require for the destroying process.

The fourth condition is that proper temperatures must exist to induce the greatest activity of the organisms.

When these four conditions are fulfilled, we have a satisfactory sewage purification plant, which will give no odors if the sewage is delivered fresh, and of which the effluent water is non-putrescent, because whatever organic matter remains is sufficiently resistant so that the necessary oxygen for the slow oxidation can be readily absorbed from the air or water into which it is discharged.

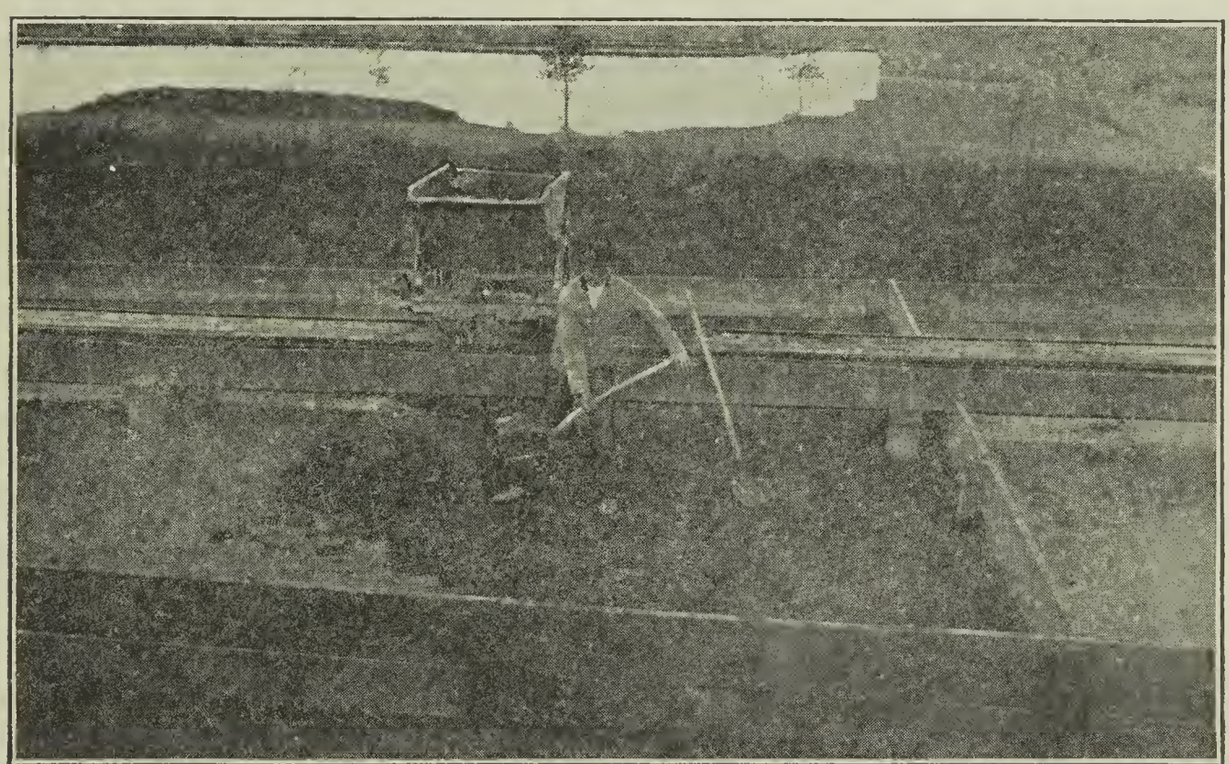


FIG. 7.—Dried Sludge from Imhoff Tanks being Thrown into a Truck for Removal at Recklinghausen, Germany.

It is not possible to dwell on the several practical means by which the conditions mentioned have been fulfilled, such as the size of grain, the depth of bed, the manner of establishing the oxidizing film, whether by contact beds, sprinkling or percolating filters, or otherwise, and the methods of sprinkling, aerating and draining. It is also not possible to more than indicate that the time during which the sewage film is exposed to the oxidizing influences is an essential factor.

The exact organic and chemical processes taking place in and upon the film are still partly unknown. There is a theory of absorption, of de-solution and congelation, one of the physical

forces which segregate the solids by attraction and the liquids and gases by adsorption, and one which almost wholly ignores the action of bacteria and limits the purification to mechanical forces.

There seems no doubt that most if not all of these forces are operating, and that in the future we may expect further economies of the processes by closer adaptation.

There also seems no doubt that the abundant insect life within coarse-grained filters is a material factor in the consumption of the fine suspended colloidal solids and that the bacteria are essential in converting most of the liquid matter. Nor can there be a doubt

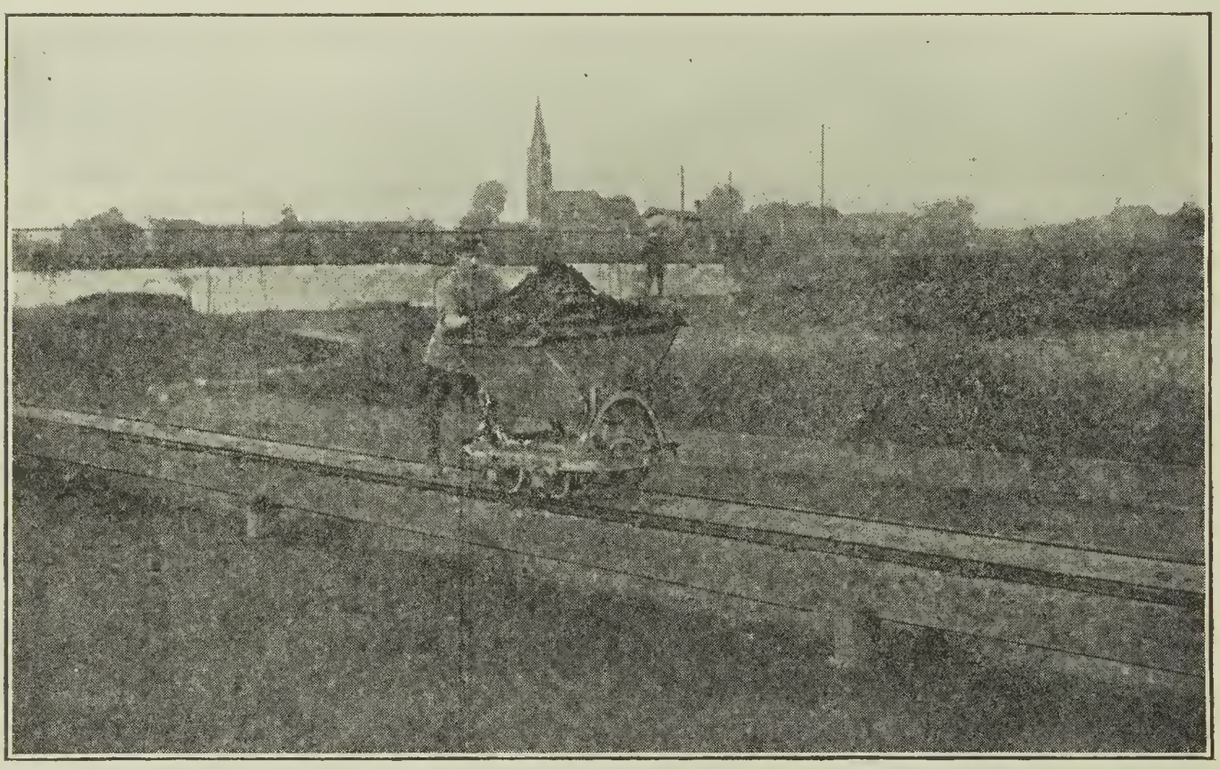


FIG. 8.—Dried Sludge being Removed at Recklinghausen. The white walls enclose the Imhoff tanks. Note the buildings in the neighborhood.

that some of the colloidal particles are liquefied and some of the liquid matter is coagulated and solidified within the filter for which the larger growths are sufficient evidence.

It is also certain that most of the solid particles will be deposited upon the surfaces of the grains by attracting forces. They may eventually fill up the pores or they may be liquefied and partly decomposed, and the more resistant parts may be unloaded, whenever the velocity of the passing liquid or its temperature changes. The development of larger growths in filters is an important factor which may help or may hinder the desired process, according to its character. The growths may be insects or algæ or other forms

of life. In short, there is still a rich field left for the chemist and biologist to survey.

The sanitary engineer has, however, sufficient information to-day so that he may design and operate sewage purification works with satisfactory and economical results. The keynotes of the present best practice of sewage purification on land are: Smooth and well-flushed sewers to deliver non-putrescent sewage; substantial separation of solids and liquids by deposition, defecation of the solids by inodorous digestion in submerged tanks, and oxidation of the remaining liquid and fine suspended matter by intensified biological action. Each of these several steps have now been sufficiently tried to prove their respective usefulness in solving the general problem.

SEWERAGE AND SEWAGE DISPOSAL IN NEW YORK AND VICINITY

By GEORGE A. SOPER, Ph.D., M.Am.Soc.C.E.
President Metropolitan Sewerage Commission of New York

Read at the New York Meeting, Dec. 9, 1910

At the present time the sewage of New York and neighboring municipalities is disposed of in the simplest manner imaginable. The sewage is discharged in crude condition at or near the surface of the water. The number of sewer outlets exceeds 500. The total quantity of crude sewage emptied into the harbor, 600,000,000 gallons per day, would fill the East River at the Brooklyn Bridge for a distance of $\frac{1}{5}$ of a mile. The population in the metropolitan drainage district is equal to the combined population of Chicago, Philadelphia, St. Louis, Boston, Baltimore and Columbus.

The sewage is plainly visible near the sewer outfalls. It discolors the water and makes it turbid; floating solid masses of fecal matter and other offensive substances are numerous. The peculiar odor of sewage in more or less advanced stages of putrefaction is evident. A film of grease lies on the surface of the water. Sludge settles on the bottom between piers and docks and there ferments, giving off gases which cause the water to assume an appearance of effervescence. These are the conditions near the sewer outfalls.

The objectionable conditions are not merely local. The main tidal channels are affected. In all parts of the harbor above the Narrows the pollution is plainly measureable by analyses. Usually it is detectable by the unaided sense of sight. Fields of sewage many acres in area may often be seen floating on the harbor water. Along 175 miles of shore the water is so polluted as to be dangerous for bathing. On the Manhattan and Brooklyn shores fishing and the handling of driftwood are attended by risk of disease. The Harlem River, in spite of the fact that it is a large stream and

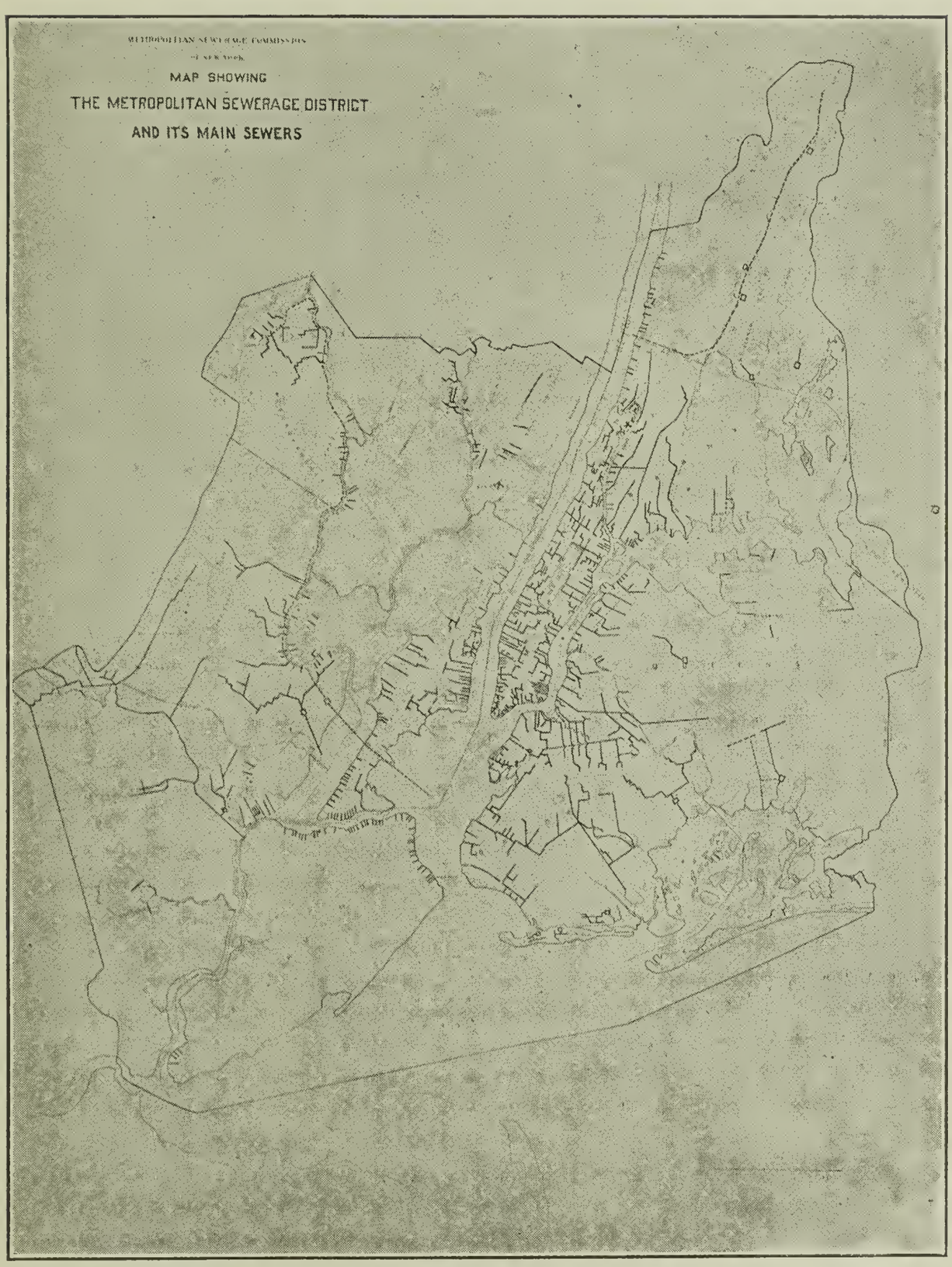


FIG. 1.—Main Sewers in the Metropolitan District. There are between 500 and 600 sewer outlets in New York and its immediate vicinity. It is impossible to show them all on a map of small size.

open at each end to the free flow of the tide, appears to be filled with sewage.

So much for the present. What the conditions of the future will be if nothing is done to protect the harbor against pollution can easily be imagined. By the year 1940 the population of the metropolitan district, which is now over 5,300,000, will be doubled. The quantity of sewage to be disposed of will exceed 1,300,000,000 gallons per day. The quantity of tide water into which this sewage would be discharged will remain the same. If the diluting power is inadequate to-day, what will it be then?

It is evidently time that something was done. The harbor should be made cleaner, not dirtier. Future generations will require cleaner conditions everywhere than are considered sufficient to-day. Sanitary standards are constantly becoming more exacting in the matter of the person, of the household and of the highway. And the harbor of New York is in reality a highway. Some have said that it should be regarded as a water park. Certainly nowhere in the world is it more necessary to keep the water of a great seaport clean.

At first sight, the way to protect the harbor would seem to be to keep the sewage out of it. Considering the subject solely from a theoretical standpoint, it would be possible to collect the sewage by intercepting sewers and carry it to a central point for purification: or it could be pumped to sea. The quantity of sewage would be great and the engineering works extensive, but it could be done.

Looking at the matter from a financial standpoint, the cost of keeping all sewage out of the harbor appears to be prohibitive. The cities in the metropolitan district are already burdened with taxation and the future requirements of subways, bridges, parks, water supplies and other public necessities are great. It is evident that no money should be spent to revolutionize the conditions of sewerage and sewage disposal in the metropolitan district unless such changes are necessary.

This raises the all-important question, What degree of cleanness is necessary for the harbor? Unfortunately, cleanness is not a condition easily measured or defined. It is difficult to find a criterion by which to judge it. It is evident that the harbor water need not be as pure as drinking water and it is safe to say that it should not be so polluted as to give rise to odors. If sewage is

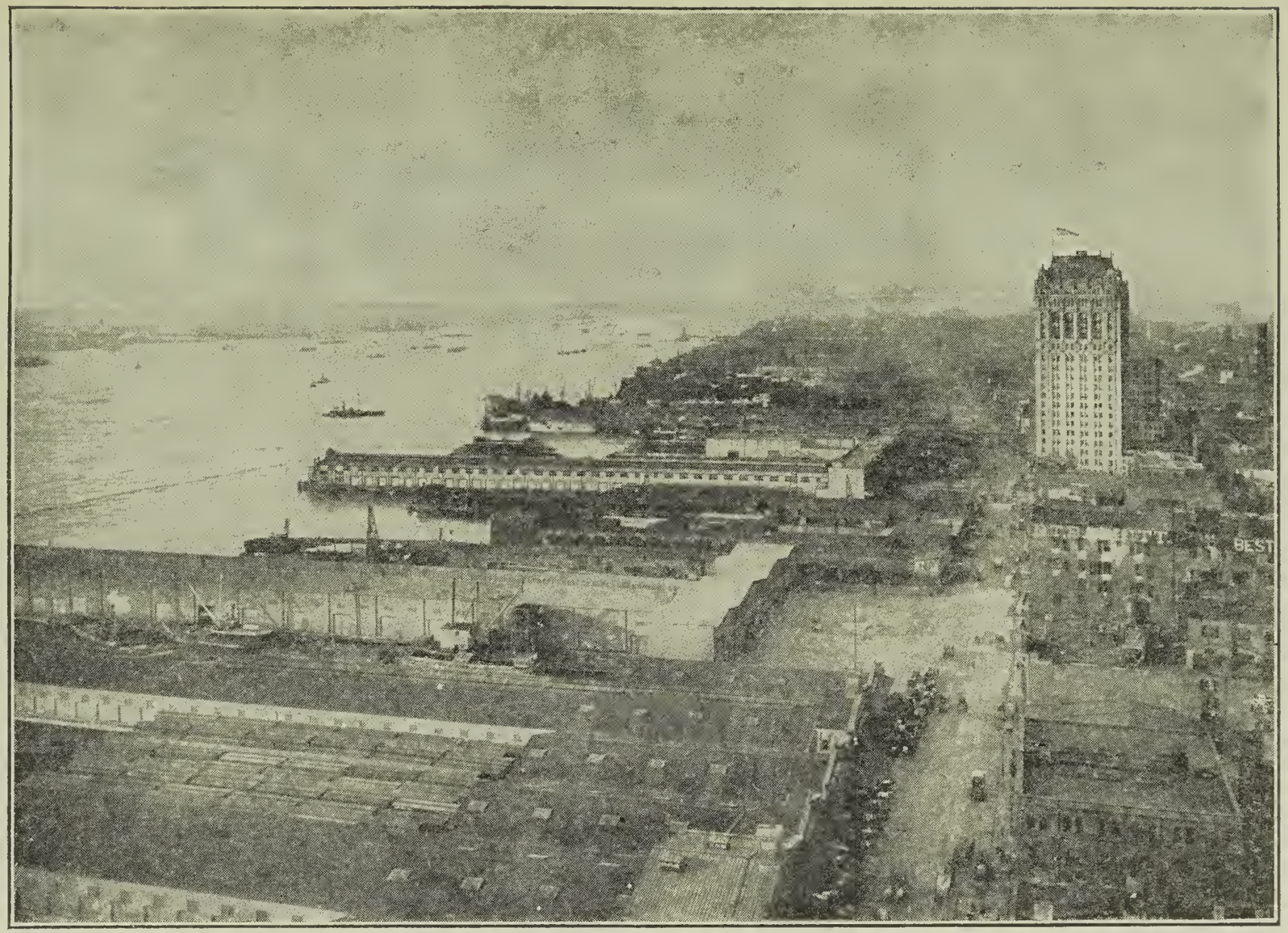


FIG. 2.—View along West Street, Manhattan. In Manhattan, the sewers are carried to the ends of the piers, but in most of the rest of the metropolitan district, the sewage is discharged at the bulkheads, bewteen the piers, or at the shore line.

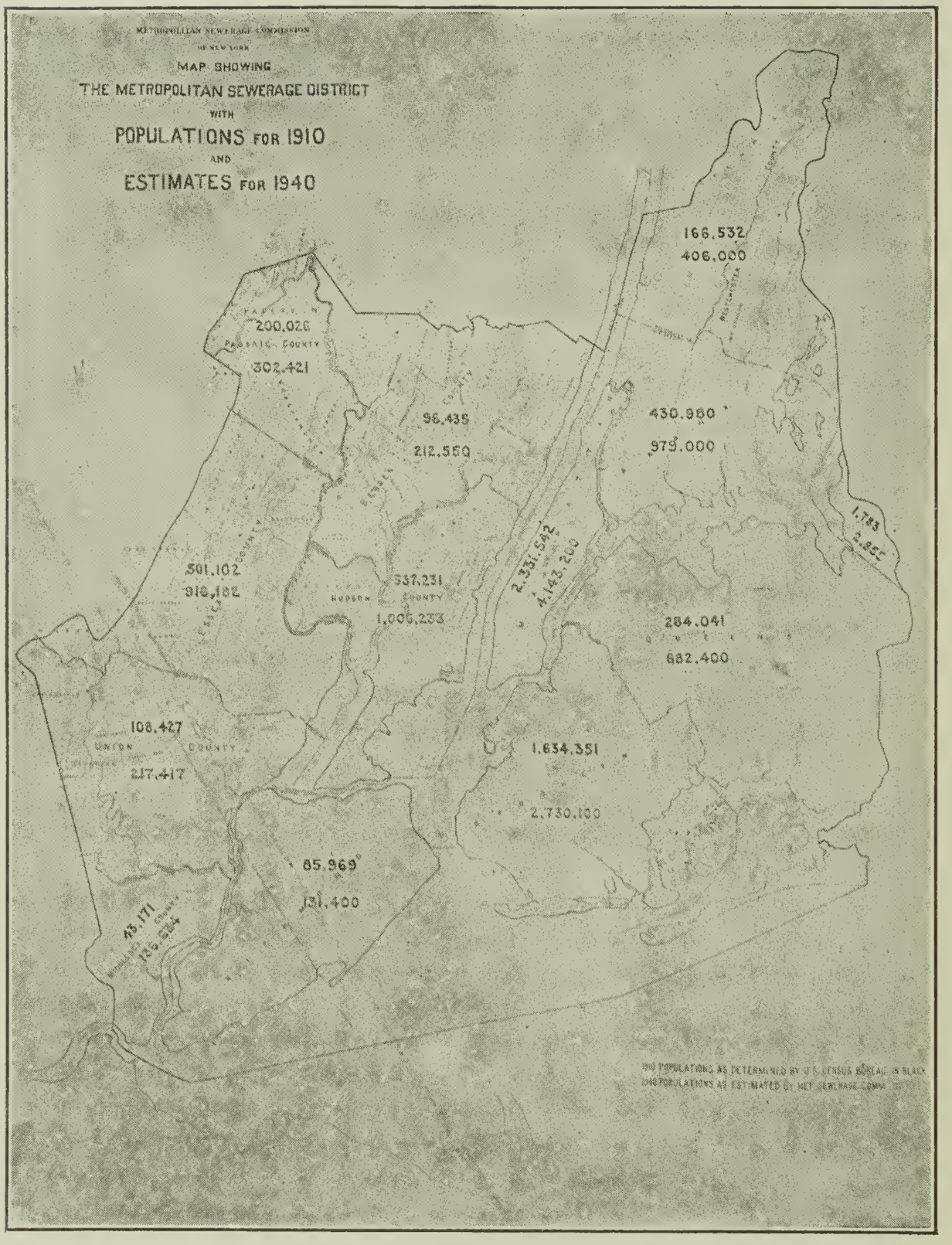


FIG. 3.—Distribution of Population.

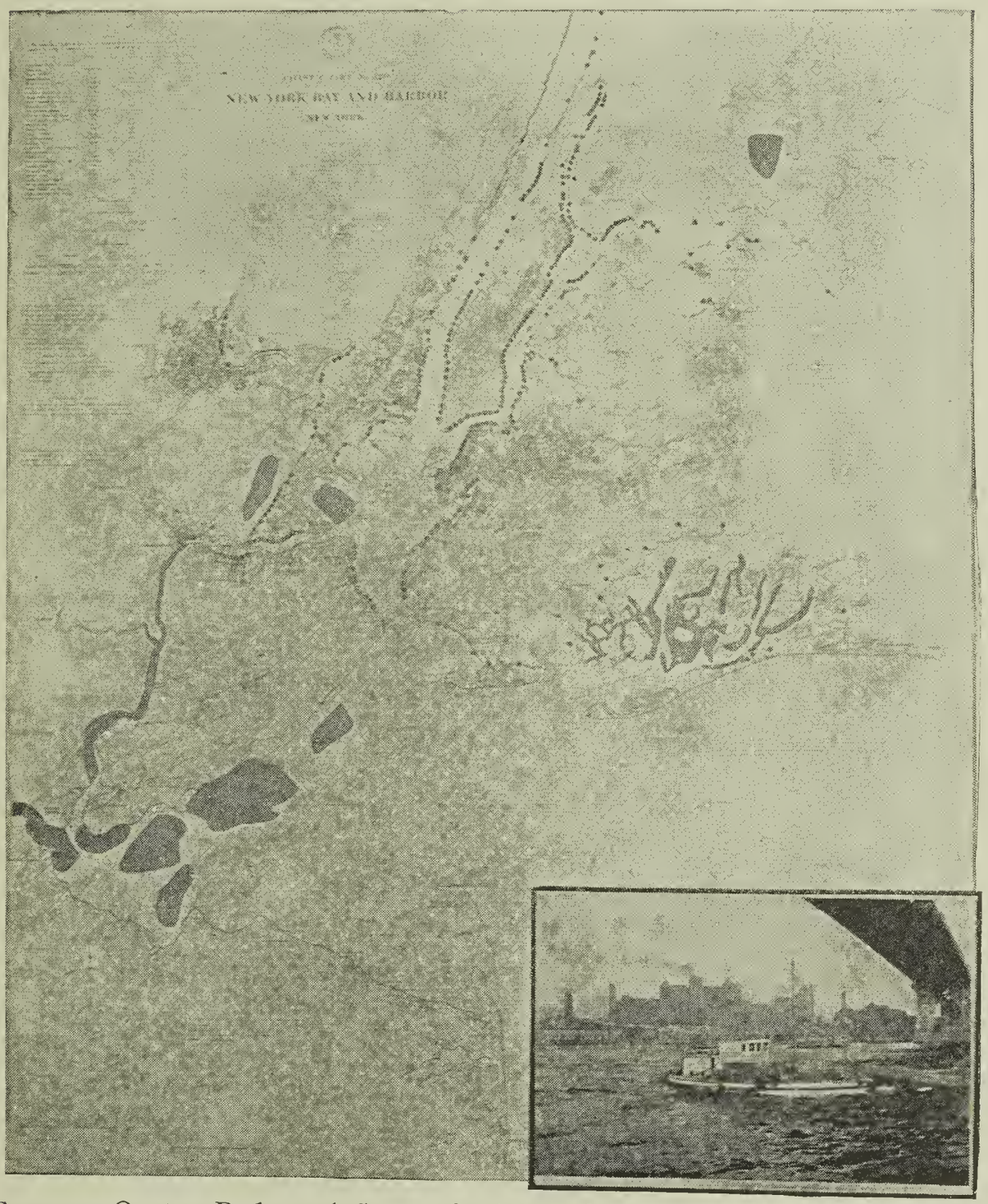


FIG. 4.—Oyster Beds and Sewer Outlets. Oyster beds are colored dark. Sewer outlets are marked as black dots.

discharged into it, this fact should not be disagreeably evident. Sickness should not result.

It would be convenient if a standard of purity could be established for the water based on chemical or bacterial analysis. Such a standard has, in fact, been proposed by Col. Black and Prof. Phelps as a result of studies which they have made concerning the disposal of sewage in the harbor for the New York City Board of Estimate and Apportionment. Messrs. Black and Phelps consider that the dissolved oxygen in the water should not fall below 70 per cent of what would be present if the water did not

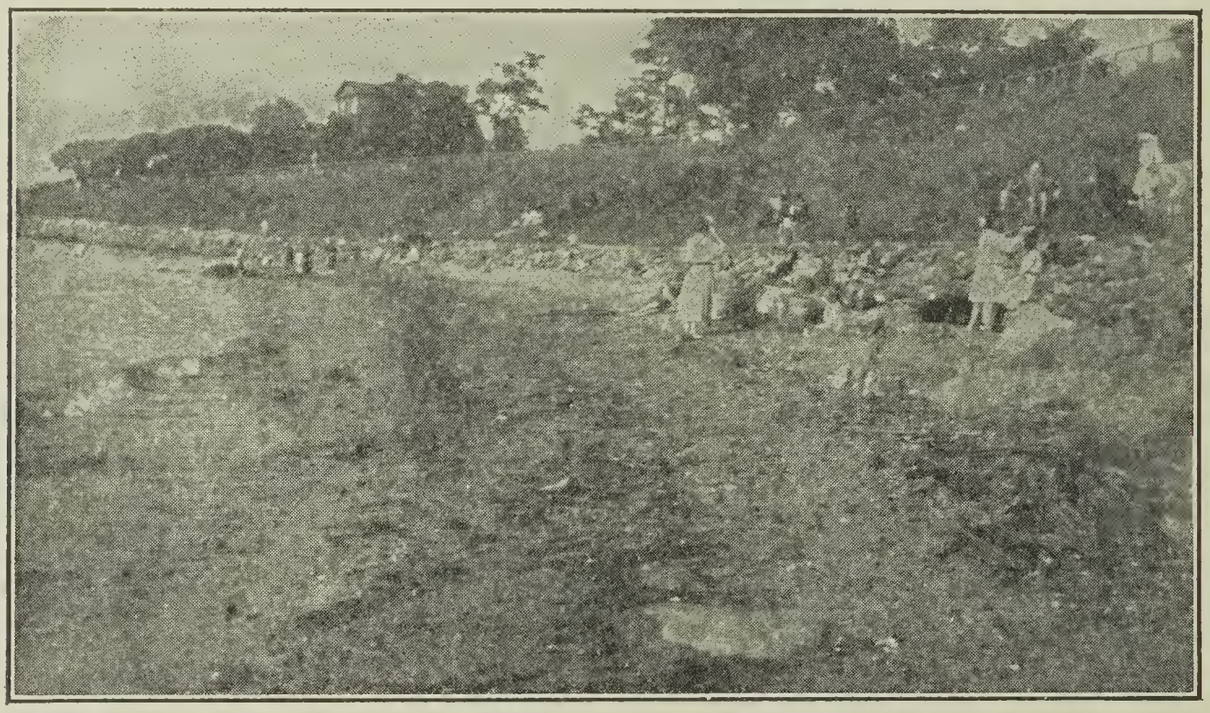


FIG. 5.—Bathing Beach in South Brooklyn. One of the many polluted beaches located in different parts of the metropolitan district.

receive any sewage. This reduction, they consider, measures the limit of sewage pollution permissible on the score of public health and welfare. But the limit proposed by these gentlemen has already been exceeded.

With the argument that no improvements can be made for want of money, there need be little concern. If ways are not now open for the raising of the money necessary to sanitate the harbor, ways must be provided. Questions which so vitally affect the public health and welfare as the prompt and permanent removal of the population's filth strike at the very existence of the port.

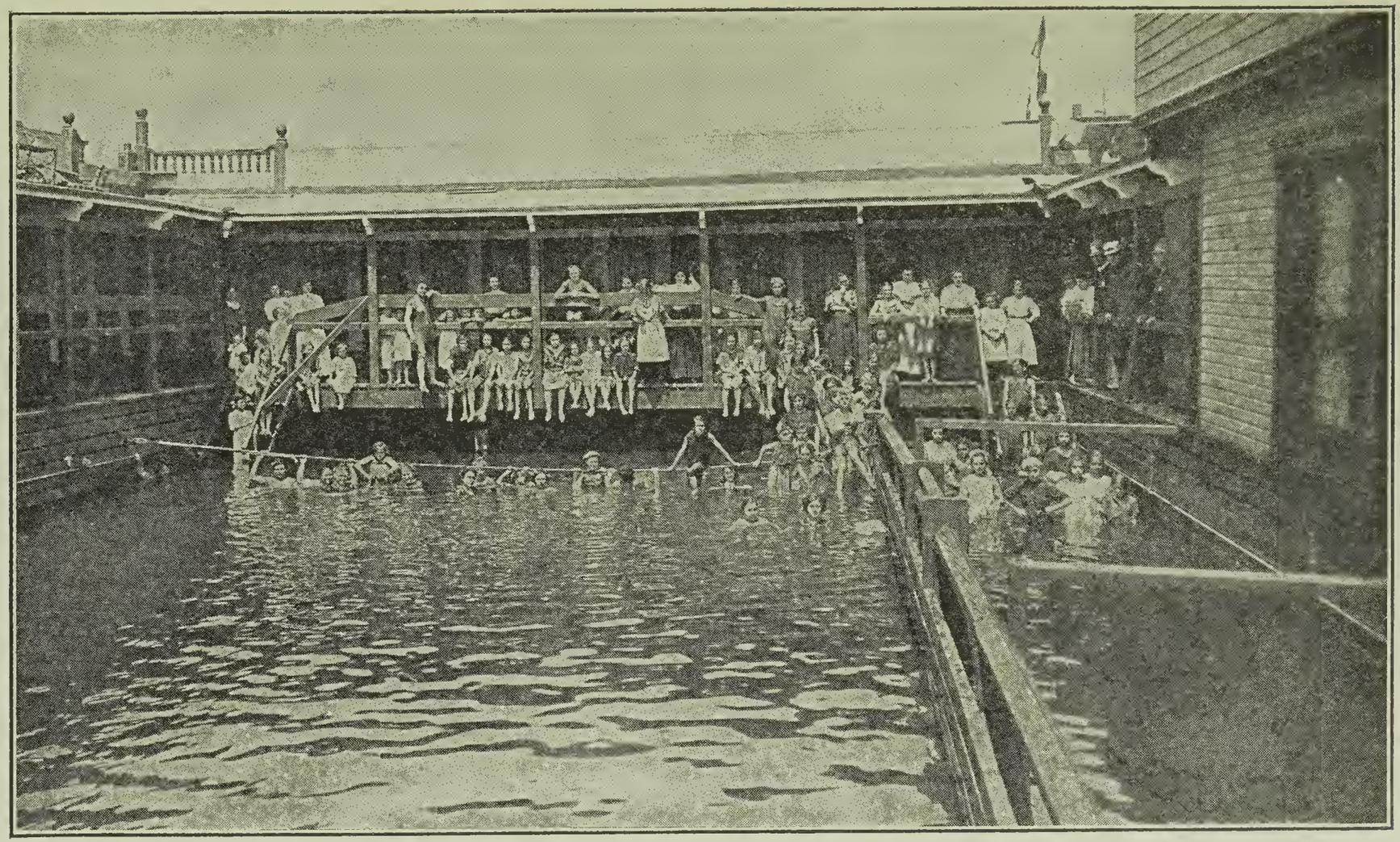


FIG. 6.—Floating Bathing Establisment. There are many of these in the metropolitan district. Within the limits of New York City alone over 2,500,000 baths are taken annually in these places. Water polluted by sewage flows freely in and out. Many experiments have been made to determine the extent to which the water in the bathing establishments is contaminated by sewage. In this work, strong solutions of uranine were put into the sewers and observers were stationed in the bath-houses to note when the dye came in. The bathers did not object to the sewage, but there were strong protests against the dye.

To what extent sewage must be kept out of the harbor must depend upon a careful consideration of what is necessary and sufficient in the different parts of the harbor. It is evident that the assimilative capacity of the waters for sewage must be utilized to some extent and that purification works will be required for much of the sewage.

Realizing that the subject of sewage disposal in New York and vicinity was one of large importance to the public and one whose difficulties placed it beyond the range of ready solution, the State and City of New York arranged, some years ago, to have the matter made the subject of official investigation. It was intended that this investigation should be sufficiently thorough to set at rest all speculation concerning the capacity of the harbor to harmlessly assimilate sewage and lay the foundation for a reasonable plan of sanitary conservancy for all time to come. The investigations were placed in the hands of a board of engineers created for the purpose, and known as the Metropolitan Sewerage Commission of New York. New Jersey was invited to participate in the studies, but did not do so.

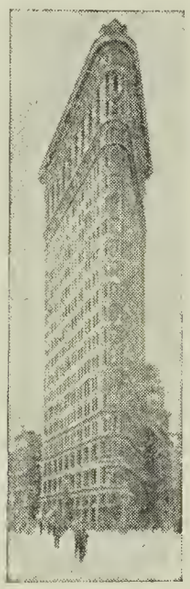


FIG. 7.—The Sewage Produced in the Metropolitan District would fill this Building every 43 Minutes.

The investigations were brought to a conclusion last May. At that time a report was issued in which the work done by the commission, including the methods and results of its many lines of study, were plainly set forth. The printed report contains 550 quarto pages, including maps and half-tone illustrations. It is divided into three parts. The first, intended for easy reading, gives a summary of the whole work. The second contains a more ample digest of the subject. The third is made up of a number of chapters which deal with the technical studies in detail. The book can be seen in the principal libraries, but cannot be sent to applicants for the reason that the demand has exhausted the supply.

The commission recommended that the present unsanitary conditions be improved in accordance with a definite plan and programme of main drainage, including outfall works and purifica-

tion plants. The details should be designed under the supervision of a central authority. The design of the works required would call for the best engineering ability available and would take several years to complete.

The duty of carrying out the recommendations of the Metropolitan Commission, in so far as they relate to the design of works, was unexpectedly put upon the commission itself. Instead of going out of existence with the completion of its investigations last May, the commission was requested to continue for three years in order to put its recommendations as to design, and in so far as they related to New York, into practical effect. This work is now progressing.

SANITARY CONDITIONS IN THEIR RELATION TO THE WATER SUPPLY IN THE VICINITY OF NEW YORK

By NICHOLAS S. HILL, Jr.

Read at the New York Meeting, Dec. 9, 1910

MILLIONS of dollars and an incalculable amount of study have been expended upon the water supply problem for New York city, and yet within the shadows of the city walls we find a heterogenous hodgepodge of local water supplies whose sources, in many instances, are inadequate to meet the daily draught in times of drought and which have been chosen with reference to their *juxtapositional* location rather than from sanitary considerations.

The many thousands of commuters who regularly work in New York city and sleep in the suburbs, as well as their families, are dependent upon these sources for their drinking water. Admitting the growing importance of contact infection through "missed cases" and "carriers," the daily presence of these commuters, who use water from the local suburban sources, should be a menace to the health of New York, a menace which cannot be measured by mortality statistics or even by the number of cases of typhoid reported from the communities in which they live. Then, too, the increasing pollution resulting from the suburban development in Queens, Nassau and Westchester, whence a portion of the water supply of Manhattan and the Bronx, Brooklyn and Queens is obtained, is a direct menace to the health of these boroughs. Many of the residents of these sections occupy lands adjacent to the sources of New York's water and a polluted local supply tending to increase the number of typhoid cases on the city watersheds cannot but leave its impress on the typhoid mortality of the urban population. Also, innumerable residents of the city visit the suburbs on every day and are thus subjected to possible infection from the local water supplies and, if infected, thereby establish additional foci of infection within the city limits. So

from several aspects, suburban sanitation is only secondary in importance to the protection of the city's immediate sources of supply.

It is not possible, within the time allotted this paper, to more than briefly outline the sanitary conditions in certain portions of the adjacent suburban territory. Brief reference will be made to Queens and northern New Jersey. I shall confine myself more especially to the conditions in Westchester County, a section which probably presents the most serious aspect.

Fortunately, among the numerous other advantages which nature has bestowed upon New York and its environs, there is an almost inexhaustible supply of underground water on Long Island; hence those communities in Queens and Nassau Counties, which are supplied with water therefrom are protected by the processes of natural purification, resulting from the passage of the water through the gravels and sands which form a large portion of the geological structure of this island. Nearly, if not quite, all of the local supplies on Long Island are from underground sources, and the water derived is usually of excellent quality, although in some cases wells have had to be abandoned on account of the local unsanitary conditions.

There are, however, certain surface sources of supply on Long Island which are a part of the municipal supplies of Brooklyn and Long Island City, which are seriously contaminated, and which are untreated and unprotected by proper sewage disposal. In the case of these surface supplies, the mitigating conditions which tend to reduce the danger from infection of the water from the Croton and the Bronx and Byram are lacking. The watersheds are nearer the city, the ponds are small, shallow and adjacent to the pipe lines or conduits, so that the "time factor," which plays so important a part in sedimentation and other natural processes for the destruction of pathogenic bacteria is much less pronounced.

The analyses of water from the streams of northern New Jersey show the effects of a progressive congestion of population. There are few streams of appreciable size in this section from which raw or unstored water of proper sanitary quality may be obtained without filtration. The reservoirs, as a rule, are designed to provide a certain daily draught of water, not primarily to give such adequate storage as to allow time for the natural processes of purification which occur only with time. There is no question

that an absolute benefit results from the prolonged storage of water in the elimination of pathogenic bacteria. On the other hand, until the safety limit of the storage necessary for purification has been determined, and it doubtless varies with the quality of the water and the season of the year, it will not be possible to rely upon this agency to too great an extent. The great variation in stream flow which should determine the amount of storage necessary for purification makes this process uneconomical, and in many cases the capacity or ability of filtration to cope with the pollution in the raw water is severely taxed.

As the urban centers of New Jersey are of larger size than elsewhere in the vicinity of New York, the larger streams must be looked to for water. There is a crying need for proper sanitation and the prevention of pollution or sewage disposal in many sections.

A general idea of the increasing difficulties which will be encountered in obtaining an adequate and pure water supply for the towns and villages of northern New Jersey may be gleaned from the following: If we take the counties of Hudson, Essex and Union, with Passaic, northward to Paterson, and Bergen to Hackensack and Englewood, nearly all of the population thus included will be, or is now, dependent upon public water supplies. The magnitude and growth of population in this section is shown in the accompanying Table No. 1. In 1930 the total population to be supplied with water will amount to two million seven hundred ninety thousand, and the probable consumption of water will amount to two hundred seventy-nine million gallons daily.

Assuming that an average daily supply of one hundred gallons per capita will suffice, the whole supply needed will be five hundred fifty million gallons in 1950, and this demand will require the total yield of approximately eight hundred square miles of watershed, the equivalent of a stream nearly as large as the Passaic and its tributaries above Paterson.

It will not be an easy matter to find such an amount of safe water, even after storage in large amounts has been developed, unless measures are now instituted to prevent the contamination of these rivers and streams which are available as sources of water supply.

In Westchester County, except for a small quantity of water which the City of New York allows to be withdrawn from its

CROTON WATER-SHED

CITY OF NEW YORK.

PEEKSKILL
FURNACE BROOK
N. Y. C. & H. R. R. Co.
FURNACE BROOK
NEW CROTON DAM
CROTON RIVER
CROTON POINT
CROTON BAY
HAVERSTRAW BAY
INDIAN BROOK
OSSINING WATER WKS.
AREA=0.13 SQ. MI.
AREA=0.07 SQ. MI.
BOUNDARY - METROPOLITAN DISTRICT
SING SING CREEK
AREA=3.42 SQ. MI.
SING SING CREEK
OSSINING
STATE PRISON
BRIARCLIFF MANOR
BRIAR CLIFF WATER WORKS
AREA=0.45 SQ. MI.
BRIAR CLIFF MANOR
CROTON RIVER
CONSOLIDATED WATER Co
AREA=1.68 SQ. MI.
POCANTICO RIVER
POCANTICO RESERVOIR
POCANTICO
GARY BROOK
POCANTICO
AREA=3.17 SQ. MI.
SAW MILL RIVER
NORTH TARRYTOWN
TARRYTOWN WATER WKS.
TARRYTOWN
RESERVOIR AREA 0.98 SQ. MI.
TARRYTOWN
SAW MILL RIVER WORKS
AREA=2.38 SQ. MI.
ELMSFORD
PLEASANTVILLE
PLEASANTVILLE WATER WKS.
AREA=0.09 SQ. MI.
WAMPUS RIVER
BYRAM
BYRAM LAKE
CITY OF NEW YORK WATER-SHED
BRONX RIVER
HENGICO RESERVOIR
RYE POND
WHITE PLAINS WATER WKS.
AREA=0.35 SQ. MI.
ST. MARY'S LAKE
NEW YORK
CONNECTICUT
NEW YORK
CONNECTICUT
GREENWICH WATER Co.
AREA=2.16 SQ. MI.
GREENWICH WATER Co.
AREA=4.83 SQ. MI.
ROCKWOOD LAKE
GREENWICH WATER Co.
AREA=1.45 SQ. MI.
LAKE
BRUSH DAM
MIANUS RIVER
AREA=27.91 SQ. MI.
MIANUS RIVER
MILL RIVER
AREA=11.79 SQ. MI.
SOXS DAM
METROPOLITAN MILL
DISTRICT
RIVER
AREA
TRINITY
STAMFORD
BOUNDARY
AREA=1.622 SQ. MI.
BYRAM
RIVER
BLIND CREEK
AREA=6.34 SQ. MI.
BLIND CREEK
HORSENECK BROOK
AREA 2.05 SQ. MI.
GREENWICH CREEK
AREA=7.00 SQ. MI.
GREENWICH CREEK
MILL RIVER
MIANUS RIVER
IRVINGTON
IRVINGTON WATER WKS.
AREA=0.11 SQ. MI.
DOBBS FERRY
ARDSLEY
WHITE PLAINS
BRONX RIVER
MAMARONECK RIVER
N. Y. INTERURBAN WATER Co.
AREA=4.79 SQ. MI.
PORT CHESTER
NEW YORK
CONNECTICUT
HORSENECK BROOK
GREENWICH
SAW MILL RIVER
SPRAIN BROOK
YONKERS WATER WORKS
AREA=2.18 SQ. MI.
GRASSY SPRAIN BROOK
RESERVOIR
YONKERS WATER WORKS
AREA=2.18 SQ. MI.
TROUBLESOME BROOK
NEW ROCHELLE WATER Co.
AREA=2.09 SQ. MI.
SCARSDALE
BRONXVILLE
TUCKAHOE
MAMARONECK WATER Co.
AREA=2.57 SQ. MI.
SHELLDRAKE RIVER
AREA=1.61 SQ. MI.
MAMARONECK
HARRISON
BEAVER SWAMP BROOK
BLIND BROOK
RYE
SHELLDRAKE RIVER
LARCHMONT
HUTCHINSON RIVER
INTERURBAN BAY WATER Co.
PELHAMVILLE
PAINES BROOK
TOM PAINES BROOK
PINE BROOK
NEW ROCHELLE
YONKERS
MOUNT VERNON
BRONX RIVER
CITY OF NEW YORK
CITY OF NEW YORK
CITY OF NEW YORK
LONG ISLAND SOUND
CONNECTICUT
NEW YORK
NEW JERSEY
NEW YORK

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conduits for local consumption, a large percentage, one might say all, of the water is obtained from local streams or surface sources.

The accompanying map gives the outlines of the watersheds of the various streams which traverse Westchester County, generally in a north and south direction.

TABLE I

DATA REGARDING THE PRESENT AND PROBABLE FUTURE POPULATION OF SUBURBAN NEW YORK, AND ITS RELATION TO THE WATER SUPPLY PROBLEM.

	Westchester County. -	Borough of Queens; - & Nassau County. -	Metropolitan District of New Jersey. - (Hudson, Essex, Union, & parts of Passaic & Bergen Co's)
(1)	(2)	(3)	(4)
POPULATION: -			
By U.S. Census in 1890. -	136,743	128,059	726,442
" " " " " 1900. -	184,257	208,447	1,041,097
" " " " " 1910. -	283,055	367,971	† 1,424,000
Estimated " 1930. -	586,000	1,057,000	2,790,000
Past Per Cent of Increase for 10 yrs	53.5%	93.6%	43%
Future Per Cent of Increase for 10 yrs. (Estimated)	53.5%	93.6%	40%
WATER DERIVED FROM LOCAL SOURCES			
1910. -	18 Mi. Gals Daily.	190 Mi. Gals. Daily.	* 142.5 Mi. Gals. Daily.
1930. - (Estimated.)	41 " " " "	380 " " " "	* 279.0 " " " "
SAFE YIELD OF AVAILABLE LOCAL SOURCES.			
Present Sources as now developed.	15 Mi. Gals. Daily.	———	△ 155.0 Mi. Gals. Daily.
All Sources, fully developed.	32 " " " "	———	† 512.0 " " " "
COST OF NEW RESERVOIRS. -			
Required to Yield 1930 Draft; All Sources. -	$10,750,000.	———	———
POPULATION PER SQ. MI. OF AREA CONSIDERED: -			
Total in 1910.	602	———	———
" " 1930. (Estimated.)	1247	———	———

† Estimated.
* " @ 100 gals. daily per Capita. -
† " @ 550,000 gals. daily per Sq. Mi. of available water-shed. -
△ " @ 200,000 " " " " " " " with 17.5 Mi gals. per Sq. Mi. as total storage. -

At the present time, the bulk of population in Westchester County is located adjacent to Long Island Sound on the New Haven Railroad and next to the Hudson along the New York Central lines.

The accompanying Table No. 1 shows that the increase in population in suburban New York is very rapid. In Queens and Nassau it has amounted to about ninety-three per cent per decade, and in the metropolitan district of New Jersey, to about forty per cent. In Westchester, the rate of increase is slightly over fifty per cent per decade. At the present time the density of popula-

tion in Westchester is six hundred and two per square mile, and estimates indicate that this density of population will have increased to twelve hundred and forty-seven per square mile in 1930. This population is not equally distributed, and the population per square mile on the watersheds of the available local streams is on the average materially less, at present, than the figure for the density of total population in the entire county. But there are watersheds in use to-day which have at least one thousand inhabitants to the square mile. The future development of this territory will be necessarily toward the north, following the introduction of new lines of transportation and the overcrowding, which will occur along the New Haven Railroad on the south, and on the New York Central on the west. This means that the proportional increase in population on those portions of the watersheds which are now possible as sources of water supply will, during the next twenty years, be more rapid than the growth of total population in the entire county.

Urban population is of much greater consequence in its effect on probable pollution than segregated rural population, and as the bulk of population in Westchester is not distributed, but centers in communities developed by real estate operators, we may expect to find a congested condition at many points in these watersheds. In fact, the character of the population development is such as to create the greatest menace to the local water supply.

Another menace of increasing importance is the growth of institutions of various kinds. The topography of Westchester County is such as to make it attractive for sanitariums, hospitals, orphan homes, industrial schools and the like. These institutions in many cases house a large number of inmates, and while numerous abortive efforts for sewage disposal have been made, these institutions do not maintain persons on their staff who are properly qualified to operate sewage disposal plants, and hence the effluents are far from satisfactory.

The general sanitary conditions on all of the local streams are poor and the nuisances are many. Almost without exception, the water courses are polluted by cattle, and most of them, at one time or another, receive human fecal matter, or the washings from privies located directly on their banks. Besides the isolated houses, there are settlements or small towns of from twenty-five to five hundred inhabitants without sewerage systems of any kind,

and where these occur, as well as on the outskirts of the larger towns, the banks of the streams are always chosen as locations for privies. In some instances the streams receive sewage and the waste from factories. Other streams receive the effluents from inefficient sewage disposal plants. It is also to be noted, that with few exceptions, the source of the stream, or some of its tributaries, is located in some barnyard where cattle stand and where it receives the stable drainage.

Table II, on page 380, gives the ratio of increase in those chemical constituents, which are usually taken to indicate pollution, referred to waters in each location which may be taken as normal. The table shows that the ammonias, nitrites and nitrates are from two to six times as high as in the normal waters, and that the chlorine is from two to three times as high as normal.

The tables also show, in some instances, that the number of bacteria is very much higher than in normal water and that B. coli are present for a large percentage of the time.

The great majority of individual pollutions, may, at the present time, be abated with comparatively little trouble or expense if the proper sanitary supervision is maintained by the small communities deriving their water supply from these sources. This may be accomplished by the removal of the adjacent and overhanging privies to a safe distance or the substitution of sanitary closets for those that cannot be removed. The contamination from cattle in the country districts may be largely eliminated by fencing the streams and springs.

The possible decrease in the existing pollution, by abatement of the individual nuisances, will, however, be offset by reason of the future increase in the population. As this increase takes place, it will not only be more difficult to cope with the individual nuisances, but collective nuisances will be created which will be expensive to control, or remedy—too expensive to be within the reasonable limits of cost to a small community or town.

Indications point to the need, not only of filtration, but of proper sewage disposal, in order to obtain a satisfactory water supply from local sources. The watersheds are small and the stream flow is limited, and it is evident that the dilution of the sewage reaching the streams will be but slight. The amount of pollution reaching the water supplies is usually heaviest in times of heavy rain when the run-off carries to the streams the surface

washings from streets, from overflowing cesspools, barnyards and other sources of contamination, the filth from which does not normally reach the streams in a fresh condition. During the flood flows, the processes of sedimentation and natural purification in storage reservoirs are least effective, unless the reservoirs are

TABLE II

RESULTS OF CHEMICAL AND BACTERIOLOGICAL ANALYSES OF SURFACE WATERS IN;-

- SOURCE -	Expressed in Multiples of the Normal for the Locality considered. - Turbidity.	Color.	Albuminoid Ammonia.	Free Ammonia.	Nitrites.	Nitrates.	Total Solids.	Total Hardness.	Alkalinity.	Chlorine.	Number of Bacteria.	% of Time, B.Coli present in 1 c.c.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
WESTCHESTER COUNTY.												
NORMAL (Parts per Million)	1	10.0	0.105	0.023	0.001	0.080	43.0	14.9	13.0	1.9	177.0	2.0%
Pocantico River.	18	2.5	2.0	2.4	2.0	2.2	2.1	—	—	2.5	170.0	— +
Saw Mill " .	27	2.6	1.2	2.0	5.0	4.8	3.1	5.0	5.2	3.3	25.0	100.0%
Croton " .	8	3.5	2.5	3.0	2.0	3.1	1.6	2.2	2.1	1.2	7.0	40.0%
Mamaroneck " .	15	2.0	2.5	6.1	5.0	0.2	2.1	—	—	3.4	25.0	— +
Byram " .	8	3.5	1.4	1.0	3.0	0.7	1.7	2.6	2.1	2.8	—	—
Putnam Lake.	14	2.5	1.0	0.5	1.0	0.6	1.1	1.7	1.1	1.7	—	—
Five Smaller Streams.	13	3.0	3.0	4.0	5.0	3.6	2.8	—	3.7	1.9	—	—
White Plains. Surface Supply.	5	2.0	1.1	1.0	1.0	0.2	1.5	1.1	0.7	1.6	33.0	60.0%
LONG ISLAND.												
NORMAL (Parts per Million)	1	8.0	0.083	0.010	0.001	0.320	38.0	11.0	6.0	5.3	434.0	4.3%
Springfield Pond.	6	3.0	1.4	4.1	12.0	9.0	2.9	3.3	2.5	2.4	3.3	17.0%
Hempstead Stream.	5	1.2	1.2	8.3	22.0	10.0	2.6	3.1	2.2	3.7	7.5	30.0%
Oakland Lake.	10	1.5	1.5	7.4	14.0	5.0	1.0	4.8	6.6	1.4	1.7	—
Millburn Pond.	2	1.3	0.7	0.9	2.0	0.6	1.3	1.4	1.0	1.3	1.0	11.3%
Schodack Brook.	1	1.3	0.5	2.0	3.0	3.6	1.7	1.7	1.3	1.2	1.5	13.9%
Clear Stream Pond.	5	1.8	0.6	1.8	9.0	15.0	2.8	3.0	1.0	1.8	2.3	9.3%
Simonson's " .	8	1.8	0.7	2.5	12.0	13.0	2.9	3.1	1.5	1.8	5.4	9.8%
Baisleys " .	8	4.0	3.4	7.2	10.0	5.6	3.4	5.1	4.8	2.0	2.9	10.6%
NORTHERN NEW JERSEY.												
NORMAL (Parts per Million)	2	18.0	0.066	0.014	0.000	0.040	65.0	34.0	27.0	1.4	200.0	0.0%
Raritan River.	44	1.5	2.5	3.5	10.0	7.5	2.8	1.5	1.6	2.4	10.0	83.0%
Passaic " .	4	1.5	2.8	2.3	7.0	6.8	1.5	1.1	1.0	2.4	12.0	—
Rockaway " .	4	1.1	2.4	3.5	3.0	9.0	1.6	—	1.5	2.6	8.0	81.0%

designed and have a capacity sufficient to provide the proper time factor or period of storage. Reservoirs of such a size will be prohibitively expensive. In all likelihood it will not be necessary to provide sewage disposal so refined as to produce an effluent which is practically free from infection, but it will be incumbent to remove the putrescible organic matter and to obviate fouling the streams to an extent sufficient to make filtration difficult or expensive. The filters may reasonably be relied upon to remove infection, particularly if their normal bacterial efficiency is augmented by the judicious use of a bactericide. It is obvious that

the cost of the necessary purification of the water derived from adjacent streams will be high, and that it will be enhanced with each successive year.

The necessary state supervision to procure efficient sanitary protection, under existing laws and with the funds now at the disposal of the State department of Health is difficult to obtain. Pennsylvania appropriates two hundred thousand dollars per year and New York eighty-five thousand dollars. The individual community or water company cannot be expected to undertake sanitary protection, so that the solution of the problems under the existing conditions is difficult to find. It is obvious that only through the control of a central board which will be empowered to fairly distribute the cost, can the necessary safeguards of the local water supplies in Westchester be obtained.

Westchester County includes approximately four hundred and seventy square miles. Reference to the map shows that a great proportion of this area is included in the basins of the Croton, the Byram and the Bronx. The black border lines indicate the boundaries of the various local watersheds to the south of the Croton. The sum of these areas lying within Westchester County amounts to about one hundred and fifty-three square miles.

For obvious reasons, either on account of the density of population and the contamination at the lower end, or on account of the lack of available reservoir sites on the lower reaches of these streams, the total area suitable for water supply purposes is materially reduced. Certain of the streams shown are now so polluted as to be at present unsuitable, among which may be mentioned the Bronx River below White Plains, Pine Brook and Beaver Swamp Brook. Moreover, I estimate that in the near future, owing to the increased congestion of population, about forty square miles of watershed area will be rendered incapable of development, except at great cost for intercepting sewers and sewage disposal, so that it is not safe to assume that more than one hundred and three of the one hundred and fifty-three square miles tributary to the local streams in southern Westchester will be available.

One of the great difficulties to be encountered in developing these streams will be the location of available reservoir sites.

In a thickly populated section like the one under consideration, the presence of villages and towns in the valleys suitable for storage purposes makes the cost of condemnation excessive. Railroads and highways traversing reservoir sites enhance their cost as a result of the relocation, reconstruction and grading involved. Such costs may be incurred by large cities like New York, but they cannot be undertaken with the revenues derived from the sale of a few million gallons of water per day. The proximity to the reservoirs of settlements, institutions, railroads and highways will increase the care which it will be necessary to exercise in order that pollutions may not enter therein within close range of the point at which the supply is sent to the consumer. The existence of pollutions in the vicinity of storage reservoirs has no doubt in many instances vitiated the effects of the natural purification which would otherwise occur, and the probable existence of such pollutions offers an additional ground for the suggestion that only through sewage disposal and filtration can the local water supplies be made potable.

While it has not been possible to make a detailed study of each of the local streams, some study has been given to certain sheds, and it has been found that a storage of not more than one hundred and forty million gallons per square mile could be practically developed on these sheds at present. As the population increases, this figure will be constantly reduced.

At most, not more than forty to fifty million gallons of water per day can be economically impounded and derived from local sources.

The estimated consumption of water in those towns and villages in Westchester County lying outside of, and south of, the Croton watershed will in 1930 approximate forty million gallons daily. It appears, therefore, that the development of the local surface sources of supply, even though costly, will be but tentative.

These statements may be, to some extent, modified through the development of underground water sources, but to date the available water-bearing strata in this section have been found to be very limited and the quantity derived from wells is very small. Reference to Table I shows that at this date the estimated maximum safe yield of the present sources of supply is less than the present average daily consumption.

We have all read of the water famine which has existed during the past summer, and it is only necessary to briefly refer to the danger resulting from a continuation of these conditions. The consumer is forced to find water where he can, often from polluted domestic wells or from nearby sources whose sanitary qualities have not been determined. Then, too, personal and domestic cleanliness are more and more recognized as the great preventive in the spread, not only of fecal-borne or water-borne diseases, but of infection of all kinds. Sanitary conditions cannot be maintained in the home unless there is an adequate and sufficient supply of wholesome water.

Reference to the map shows that the communities in Westchester are limited to the local streams. To the south is Long Island Sound, to the west the Hudson River, to the east is the Connecticut boundary line. The abstraction or diversion of water from streams in the last-named State may involve interstate complications. A goodly quantity of the water which is used by Port Chester and adjacent villages comes from over the Connecticut line, but the amount of diversion is not sufficient to warrant serious notice at present. In fact, the best waters obtained by the Westchester towns come from Connecticut. It is a question to how great an extent this diversion will be permitted, particularly when the water of the Connecticut streams is needed for local consumption in the rapidly growing communities along the Connecticut shore of the Sound.

The only apparent direction in which water supplies, free from serious contamination, may be obtained, is to the north, unless the expense of crossing the Hudson is involved. To the north we find that the City of New York has pre-empted those streams which are most available, namely, the Croton, the Byram and the Bronx.

The expense involved to the individual community of seeking a purer source of supply to the north of the Croton, or of crossing the Hudson, is so great as to preclude its practical consideration. It seems, therefore, that unless a metropolitan water board is created, such as has already been established in the vicinity of Boston, which is empowered to provide sources of supply and to distribute the cost to the several towns and villages in Westchester, no permanent relief can be obtained. The importance of

creating such a commission at an early date is evident. If this is not accomplished, it seems apparent that the City of New York in self-protection and out of consideration for its own sanitary environment, will be required to arrange to furnish water in the necessary quantities to the towns and villages lying immediately to the north.

UNSOLVED PROBLEMS OF SEWAGE DISPOSAL

By Professor C. E. A. WINSLOW

Read at the New York Meeting, Dec. 9, 1910

THE admirable papers presented at this meeting show how much has already been done in practically meeting the difficulty which confronts a city in the disposal of its liquid wastes. The yet unanswered questions have, however, a unique interest of their own; and of these sewage disposal still has its share.

The successful treatment of sewage involves the attainment of one, or all, of three main ends: the elimination of suspended solids, the oxidation of organic matter, and the destruction of pathogenic bacteria. Sometimes one, sometimes another is required, and the extent to which each must be carried depends on local conditions. Each of these objects can now be reached, at a cost which is not prohibitive, but each involves many difficulties which have not been satisfactorily met and which make our present plants more costly and less efficient than they ought to be.

The third of these primary aims, the destruction of pathogenic bacteria, has only recently been attained, and yet it is to-day more easily realized than either of the others. The application of bleaching powder solution to sewage or effluent furnishes a ready means of destroying a large proportion of the bacteria present (99 per cent and over), at a reasonable cost, and this process of sewage disinfection will yield an effluent which can be discharged into any ordinary body of surface water with the certainty that it will improve rather than injure its sanitary quality. Even here, however, there is one practical difficulty which deserves the serious attention of the engineer. In a large plant it is comparatively simple to arrange automatic devices, which will deliver a fairly constant supply of bleaching powder solution; and in such plants attendants are usually at hand to make up for any deficiencies which do arise. In a small plant

on the other hand it is impossible to secure constant supervision. We must rely to some extent on automatic apparatus. It is exceedingly difficult, however, to apply a strong solution of bleach in small amounts without using devices which are frequently out of order. Small holes quickly clog, small weirs crust over, and it is a common experience to find such plants stopped up and entirely inoperative. Improvements along this line are greatly to be desired.

The most fundamental of the three aims of sewage purification is perhaps the oxidation of its putrescible organic compounds, for the stimulus to the construction of disposal plants comes far more often from offense to the senses than from any danger from pathogenic bacteria. Organic stability may be economically attained by any one of the three biological methods, intermittent filtration, contact treatment or trickling filtration. More direct chemical or mechanical methods of oxidation may some day be made practical. Rideal's Guildford experiments indicated that the addition of hypochlorites to a septic effluent not only did away with the odors of decay, but facilitated the work of subsequent filtration. The forced aeration in Col. Waring's filters was probably accompanied by more or less direct chemical action. It remains to be proved, however, that any mechanical process can rival in cost-efficiency the mechanism of the trickling filter which brings together the three factors, sewage, bacteria and oxygen, in so simple and satisfactory a manner.

The problem of distribution on the trickling filter is still of course a mooted one. The English moving distributors of various types give good results, but are costly and frequently out of order. Fixed sprinkler nozzles, if of small opening, like that used at Birmingham, require much care (the constant attention of one man to an acre and a half of beds). Nozzles of large opening, like that devised at Columbus, give imperfect distribution and discharge such a large volume of liquid that they must be operated under a variable head. If the necessity for intermittency be granted, and the writer is not acquainted with any large orifice nozzle which gives even distribution without it, it seems more logical to adopt a nozzle like the one worked out at Waterbury by Mr. Taylor, which is frankly designed to discharge in a thin restricted sheet which under intermittent operation moves back and forth over the wetted area. The Gravity Distributor, designed

at the Sewage Experiment Station of the Massachusetts Institute of Technology, in which the sewage drops down on to a concave disc from which it splashes upward and outward, seems to have justified itself as an alternative to the nozzle system which is worthy of consideration. Mr. Hammond, at Mount Vernon, has made an important improvement in the splashing disc by turning it over at the edge; and the plant now in operation at Mount Vernon shows that the gravity system may yield excellent results in practice, and on a large scale.

One other point which deserves attention in future studies of the oxidizing phase of sewage purification concerns the intensive possibilities of the intermittent sand filter. The original experiments at Lawrence pointed to a maximum rate of 100,000 gallons per acre per day, and in practice the Massachusetts plants have fallen below this figure, except perhaps at Gardner and at Worcester. Many of them have operated at less than half this rate. With the Massachusetts practice of applying crude sewage to the beds such low rates are necessary, for the winter clogging sets a sharp limit to their capacity. If, however, suspended solids were removed by proper preliminary treatment it seems probable that a much higher efficiency could be maintained. A dose of 100,000 gallons on an acre corresponds to a depth of less than four inches of sewage. With a clean bed of fairly coarse sand, well leveled and equipped with good distributors, such a dose disappears in half an hour and may be repeated once every six hours without the slightest interference with nitrification. In the middle-western States (as at Wauwatosa, Wis., for example), plants designed on this principle with a septic tank preceding the sand filter, are said to operate with success at a rate of 400,000 gallons per acre per day. Analytical data are unfortunately in most cases not available. An experimental outdoor sand filter dosed with septic effluent for over a year at the Sewage Experiment Station of the Massachusetts Institute of Technology has, however, yielded results which are very favorable to the intensive process. The filter, operated under the direction of Prof. E. B. Phelps and the writer, is a square bed 21′×22′ in plan and contains 3.5′ of beach sand with an effective size of .36 mm. From August, 1909, to May, 1910, it received septic effluent at a net rate varying between 220,000 and 340,000 gallons per acre per day, the sewage being applied from a dosing tank discharging about four times in 24

hours. The filter effluent has averaged 3.1 parts per million of free ammonia, 5.9 parts of organic nitrogen, and 19.1 parts of nitrates, with a relative stability of over 96. During this period of ten months the surface of the bed was raked six times, but no material was removed and there was no sign of deterioration in the character of the surface. The operation of sand filters at rates of 200,000 gallons and over after careful preliminary removal of suspended solids seems promising enough to warrant more extensive study on a practical scale.

The third problem, the removal of suspended solids from sewage, is the one that still presents the most serious difficulties. In regard to the other two phases of the subject, the destruction of pathogenic bacteria and the oxidation of putrescible organic matter, we are concerned with the perfecting of details and with the choice between alternative and promising methods. In regard to the disposal of the solid constituents of sewage, on the other hand, there is no method which has been developed to a point of real efficiency unless it is the Imhoff tank, of which Mr. Hering brings us such favorable reports. At many plants in this country the whole problem is ignored as if it did not exist.

It is quite feasible to separate the solid particles from the fluid stream, the coarser by screening and the finer by sedimentation, alone, or aided by chemicals, or supplemented by septic action. How far it is economical to go in the removal of suspended solids, and how far it is cheaper to accomplish this end by the use of fine screens rather than by sedimentation, are minor questions which must be answered largely on the ground of local expediency. The difficulty which is everywhere and always present is that of disposing of the semisolid sludge. It was once maintained that no sludge was produced in intermittent filtration. The deposit on sand beds is dryer and less obnoxious than the sludge formed by other processes; but the removal of 5 to 10 tons of such material for every million gallons of sewage filtered is not a task to be ignored.

The watery sludge from sedimentation processes amounts, with American sewages, to 15 or 20 tons per million gallons when chemicals are used and to 10 or 15 tons with the process of plain sedimentation. Septic treatment, from which so much was hoped, somewhat reduces the problem, but by no means eliminates it. By the consolidation of the sludge during its storage in the septic

tank and by the liquefaction of a quarter to a third of its solids, the amount of sludge from the septic process may be brought down to 5 tons per million gallons of sewage. Even this amount, however, is enough to offer a serious difficulty in sewage purification for inland communities. Maritime cities can dump their sludge at sea without great expense. For small plants land disposal is generally available. In larger projects not situated near the ocean provision must be made for mechanical drying, followed by land disposal or burning of the dried sludge cake. None of these processes is free from its objectionable features and all add materially to the cost of disposal. Improvements in practice which would lessen this burden on the sewage purification plant are perhaps more to be desired than any other advances in the art.

The first possibility which suggests itself is that of a further reduction in the amount of sludge to be disposed of by more effective liquefying action than is attained in the ordinary septic tank. Of 14 septic tanks where careful records have been kept in this country and in England, 5 show a solution of deposited solids of 30 per cent or less, 4 are between 30 and 40 per cent, 3 between 40 and 50 per cent and only 2 over 50 per cent. It is natural to inquire as to the factors which check the liquefying process and prevent a more complete destruction of the organic solids. Laboratory experiments carried out at the Sanitary Research Laboratory of the Massachusetts Institute of Technology led to the conclusion that the most important of these factors was the accumulation of the waste products of the septic process itself. This is a common phenomenon in all bacteriological reactions, the removal of the end-products being almost invariably a necessary condition to insure maximum activity. If, however, this conclusion is justified, the German deep tanks of the Imhoff or Essen type would appear to be designed on a wrong principle, so far as liquefaction of solids is concerned. They are intended, of course, to separate the sludge as quickly as possible from the flowing sewage and to concentrate it in a lower chamber, where it is exposed to intensive septic action. The main idea is to keep the flowing sewage fresh and free from the products of decomposition, so as to minimize the odor in the neighborhood of the plant. This in itself is a great gain. The remarkable thing, however, is that Mr. Hering and Mr. Charles Saville and others who have studied the Imhoff tank find that it actually does effect a very successful

liquefaction of the sludge in spite of a concentration of decomposition products which might be expected to limit the activity of liquefying organisms.

The factors involved in septic treatment are so complex that it is hard to arrive at general conclusions without comparative studies of many different sewages. Variations in chemical composition markedly affect the whole course of the process. Columbus sewage, for example, contains sulphates in considerable amounts and produces an undue amount of offensive sulphur compounds. At Waterbury, Conn., on the other hand, the septic process in experimental tanks was notably inoffensive. We greatly need fundamental laboratory studies of the exact chemical change involved and of the bacteriological agents which set them in motion.

Professor Phelps and the writer have been working during the past year or two along lines which appear at first sight to be quite opposite to those upon which the Imhoff tank was planned. We have been using a deep conical tank, of the Dortmund pattern, with an inflow at the bottom and an outflow at the top, the sludge being constantly washed in a current of fresh sewage, so that the products of decomposition may be removed. This was operated on the septic principle, sludge having been removed only once in 15 months' operation, and then only for the purpose of analysis and not on account of any undue accumulation. The effluent has apparently not suffered from contact with the sludge. The tank removed 50 per cent of the total solids it received, and the effluent was the one successfully applied to the sand filter at high rates to which reference has been made. Analyses of sludge and tank contents after eight months of operation (during cold weather for the most part) showed that 72 per cent of the total deposited solids and 81 per cent of the deposited organic solids had been liquefied, a result so encouraging as to warrant further study of this new type of biolytic tank.

It may be possible that the Imhoff tank and our tank at Boston are not really working on such different principles. Mr. Hering says of the German tank in a recent article in the *Engineering News:* "Further, in order to prevent the gradual reduction of bacteria in the sludge by the development of toxins, the digested sludge is frequently withdrawn in small quantities, which permits frequent internal movements and the exposure of fresh surfaces of sludge every few days to renewed bacterial activity, thus main-

taining much better conditions than in the septic tank for continuous activity, and for the selection of the most favorable species." It may be that this frequent removal of sludge accomplishes the same results reached in our tank by the constant upward flow. Interesting comparative results may be expected for the Chicago experiments, where the Technology tank and the Imhoff tank are being studied side by side. There is general agreement, in the conclusion that the conditions in the ordinary septic tank are not favorable to the most efficient and inoffensive liquefaction of sewage sludge. Whether this can be remedied by making conditions in the sludge chamber more or less septic remains to be clearly demonstrated.

One word might properly be said in closing, before a Society of Industrial Chemists, in regard to a quite different alternative, the utilization of the sewage sludge. Native sludge has not proved very successful as a fertilizer; and so far the extraction of pure substances has not been economically accomplished except at cities like Bradford, England, where the sewage contains a large amount of fat from industrial establishments. The fact that success has not been attained in the past is, however, no bar to future attainment. With the improvements which are being made in drying and separating machinery nothing can be called impossible. The disposal of factory wastes is already recognized as primarily a problem of utilization rather than disposal. Even ordinary domestic sewage sludge contains, when dried, 2 or 3 per cent of nitrogen and 5 to 10 per cent of fat, and on distillation yields ammonia, tar, oil and a more or less luminous gas. There is a field here which I am inclined to believe may yet at some future time be occupied by the industrial chemist.

Discussion

Mr. G. W. Fuller:

I think this symposium has provided a most valuable and interesting review of the subject. To my thought there are two facts which stand out conspicuously. One of these relates to the residuum of dissolved oxygen which may safely remain in a water to which sewage has been applied. The other relates to the digestion of sewage sludge. I have been much interested in listening to Dr. Soper's statements that the commission here in New York is considering as a proper residuum 70 per cent of the

dissolved oxygen in the waters into which the sewage of this city is discharged. The purpose of that is to guard particularly against offensive conditions as to sight and smell, and partly perhaps to protect shellfish and major fish life. With respect to guarding against objectionable odors I think it is clearly necessary for the chemists and bacteriologists to keep in mind that putrefaction does not exist so long as oxygen remains at all. In fact, you can go further than that, and say that so long as oxygen is available from nitrates, nitrites, or other oxidized salts, there is substantially no putrefaction. I am aware that that does not provide for one feature that may be of some importance, and that is the protection of major fish life. I believe, however, that the European custom in many places is sound in indicating that 30 per cent of the dissolved oxygen necessary for saturation provides a reasonable margin in the case of a majority of species of fish life of the larger kinds. Perhaps some may call for more, but so long as there is 30 per cent remaining at all places at all times, it is a matter of deduction from our well-established laws of biology and chemistry that there can be no putrefaction. The larger number of the principal rivers in this country serving as public water supplies do not contain as much as 70 per cent of the oxygen necessary for saturation. Among the rivers with which I have been personally familiar through analysis, I may mention the Merrimac River at Lawrence, Mass. Twenty years ago it had as low as 50 per cent and sometimes but 30 per cent of dissolved oxygen. In those days it served as the water supply for Lawrence without being filtered, and in the last seventeen years, since filtering, it has been regarded as one of the good water supplies of the world. I believe that if this 70 per cent margin suggested by Dr. Soper were applied to Lawrence, it would show that the Merrimac River at that place was not providing a proper disposal for the sewage at Lowell and the cities above, notwithstanding the fact that it provides an excellent water supply at that point.

With respect to the question of anaerobic conditions, I have one point in mind, which is that specific action does not become established with anything like the facility that some people think. You frequently hear of sewage becoming septic as it reaches the outfall; that the oxygen becomes exhausted, and all bacteria die that are accustomed to live in the presence of oxygen. Now the change from the aerobic to the anaerobic condition is not

immediate; it takes time to produce enzymes and bacilli and those substances through which they produce solvent action on the solids. I believe that the isolation of the sludge in separate compartments marks one of the greatest steps in advance that has been taken in sewage disposal in the last few years. There are several things which have been impressing me during the last few weeks, as to the reasons why the necessity for that arises. I have had occasion in connection with the sewage disposal works at Plainfield, N. J., to study the experiments recently made there by Mr. Lenfries, the chemist in charge. The sewage is diluted with a water supply of considerable hardness. It is screened through half-inch bar screens, and goes into shallow septic tanks, where it is held for six or eight hours. Much bacterial action takes place, and solids are thrown very quickly to the top. Bottle experiments recently made in the large tanks show some physical factors of importance. The gas evolution, which seems to be always found in sewage when dissolved oxygen exists, throws suspended matters to the surface, and a rather tenacious crust, which does not undergo putrefaction, is formed. We have rarely any trouble at Plainfield with regard to the odors about the filters. There is almost none at the tanks, except within the immediate vicinity, say, within two hundred feet. When they are cleaned out there has to be contended with the undecomposed scum which undergoes putrefaction in the sludge beds. This suspended matter seems to be held in part above the flow line, and above bacterial action. Another thing which has been shown by bottle experiments, in which bananas and vegetables have been used, is that the gas evolution seems to take suspended matter up to the flow line, surround it with an envelope of gas and protect it from the bacteria. There are many phases of the physical side of the question which we must learn in dealing with the Imhoff tank. Gas evolution in this tank is of much advantage. Dr. Imhoff himself attaches much importance to the use of water under pressure, by which he can stir up and bring to the surface all fresh material to those bacteria which otherwise, perhaps, would be living week after week without food, and perhaps gradually dying in places where toxines surround them. In treating the antecedents of the Imhoff tank mention was made of Hampton, England. The methods used there were less satisfactory than those used at Essen. The Hampton work was all

predicated upon American investigation. In earlier papers Dr. Travers makes considerable mention of careful work done at Lawrence, which was the first scientific basis of anaerobic bacterial decomposition or putrefaction of sludge. There are some things we do not know about. One of them is that we cannot control as well as we should like the different species of bacteria or flora which are effective. With respect to sulphur, there is a great deal to be said, as to the different complications and reactions possible. In many places in this country, and especially in Birmingham, England, hydrogen sulphide is undoubtedly produced. Hydrogen sulphide will not become a factor until there is produced sufficient to combine with all the iron present, which throws it down as ferrous sulphide, and then it escapes into the atmosphere unless the iron is oxidized as at Birmingham. I believe that, among other places, at Columbus, Ohio, they have made a number of investigations on a small scale, and have found that there is no reduction of sulphur contained in mineral solids. The sulphur found was organic sulphur split up by fermentation processes. When we once establish a bacteriological decomposition which brings about the reduction of calcium sulphate and salts of that sort, there will be a large amount of hydrogen sulphide. A conspicuous example (of the trouble caused by sulphur) was found in the coal region at Nuneaton, and in this country at Los Angeles and Buffalo, where the air flowing above the liquid in the sewer oxidizes the sulphur compounds, forming sulphuric acid, which really has brought about a very serious state of affairs with respect to the disintegration of brick, mortar, and cement. I believe that these conditions are capable of a good deal of control, by adding solutions of iron, for instance, to precipitate the hydrogen sulphide, and things of this sort provide the laboratory man with many problems to work out. I do not think they can always be controlled quickly, but I feel that we are on the threshold of a new era, which will allow us to wrestle with the problem, with the aid of the laboratory, with more confidence than we have been able to picture to ourselves heretofore.

Dr. SOPER:

The standard of 70 per cent dissolved oxygen has not been adopted by the Metropolitan Sewage Commission. It was proposed by Colonel and Professor Phelps in an entirely separate investigation, and has not the endorsement of the Commission.

Mr. Geo. S. Webster, Chief Engineer of the City of Philadelphia.

Mr. Chairman, Gentlemen: The City of Philadelphia has conducted a number of experiments on sewage disposal during the last year. The sewage used was similar in some respects to that used in the Columbus experiments and contained on an average about 200 parts per million suspended solids. It was obtained from an intercepting sewer, draining a territory which provided not only domestic sewage, but considerable manufacturing waste. In the territory drained there are paper, cotton, and woolen mills: gas and dye works; in fact almost every class of manufacturing waste went into the sewers.

Among the processes used was an Emscher tank, probably the first one in operation in this country. The sedimentation chamber was but $4\frac{1}{2}$ feet deep, which is considerably shallower than those designed for practical works, and consequently did not produce as large an amount of sedimentation as would be expected from a large-size tank. The results show that about 53 per cent of the suspended solids (as measure by the Gooch crucible) were collected in the lower chamber; this represents about 80 per cent of the settling solids according to Dr. Imhoff's method of determination. The sludge was allowed to collect and remain in the lower part of the conical chamber three to four months and was drawn off in small quantities at frequent intervals; it was a dark granular mass, having a slight tarry odor entirely free from hydrogen sulphide. When placed upon a sand-bed to dry, the entrained marsh-gas (being relieved from the hydrostatic pressure of the tank) expanded, so that the sludge rose like dough, the surface cracked open, which allowed air to penetrate and facilitate in drying the mass. It was fit to shovel in a few days, and when removed was odorless, porous, and like humus in appearance.

The Imhoff or Emscher tank gives promise of a method of digesting and concentrating sludge, reducing the moisture content, so that a smaller quantity of sludge and less odors are to be expected than are usual at sewage purification works. In the small tank used in the experiments sludge as withdrawn contained on an average 82 per cent moisture and it is believed that from Emscher tanks now being constructed at the Sewage Purification Works on the Pennypack Creek in Philadelphia sludge of 75 per cent moisture will be obtained.

Mr. Hammond:

I should like to ask Mr. Webster what the conditions around the tank were. Whether it is a built-up district in Philadelphia?

Mr. Webster:

There are no dwellings within about a quarter of a mile of the testing station where the tank was located and there was no odor. The gas which escaped was simply marsh-gas, and there was no evidence of hydrogen sulphide coming from any part of the tank.

Mr. Stillwell:

I would like to ask whether any commercial use is made of the sludge obtained from these works. What do they do with the sludge?

Mr. Hering:

You will recognize that the process is quite new. It is only about two or three years old. At the present time the sludge is spread out over the surface of the ground, or dumped in piles some ten feet high until it can be disposed of in other ways conveniently. It is ready to spread over the surface of the soil, and raises very good grass or anything else. It is quite capable of being used something like garden loam, which it resembles in appearance and odor.

Mr. Stillwell:

The reason I asked was that within the last two days a material which came to me as sewage sludge was found to have a value of $6.00 a ton as a fertilizer on account of its ammonia content. It contained nearly 3 per cent of ammonia with some potash and phosphate.

Mr. Hering:

I would like to correct some impressions. When I was in London this last summer I saw Mr. Fitzmorris, Mr. Cloud, and all the other gentlemen who had to do with this London sewage. They said: "We are entirely satisfied. We do not want to do anything else so long as we can keep the oxygen dissolved at 30 per cent." There is no objection to this method, even from the gentlemen of the water supply and the celebrated Dr. Houston. I heard nothing about the Thames River being a nuisance. It is entirely satisfactory.

Also in Hamburg. I have been there perhaps twenty times. The water in the river there and in the Delaware at Philadelphia look exactly alike—just about the same as far as turbidity is concerned. With regard to the pollution of water supply there, I think we should realize that the cholera epidemic in Hamburg in 1892 was caused, not by the sewage, but by the ships which put the cholera into the water, which then circulated and got into the water supply, which was not then filtered. It was not the sewage from the city which did it, and we have always to encounter danger from that source.

Then about Birmingham. My friend Professor Winslow said that there was a good deal of trouble about cleaning the nozzles on the sprinklers, and that it required one man per acre. That is true, but since then and about three years ago a start was made towards overcoming this, which was still under way this last summer. The sewage is given a treatment between the sedimentation tanks and the sprinkler tanks resulting in taking out the fine suspended matter. Now one man cleans four acres, which reduces the expense of maintaining the sprinklers 75 per cent.

Another point about the reduction of sludge in the septic tank. As a matter of fact you know that if you have a substance containing 95 per cent of water, and another containing 45 per cent you have diminished your bulk one-half. You reduce your sludge at these sewage works very much more by getting it into a condition in which it won't hold water than by this bulk loss by septization. The advantage from the latter is small compared with the advantage of getting this sludge into a condition where it will easily drain.

Dr. SOPER:

I got my information from Fitzmorris, too. I have nothing to retract in that, and Mr. Hering has confirmed what I said as to the turbidity of the water at Hamburg. Dunbar showed me the paths of floats which went about in the Elbe, and from which he drew the inference that the water supply was undoubtedly influenced by the sewage of Hamburg.

Mr. HERING:

I spent a whole day with Dr. Dunbar in his launch, and there is no question but that this sewage from Hamburg oscillates up

and down the river, and that it goes beyond the intake of the Altona water supply, which is several miles above the town. The sewage from some 900,000 people all passes through Altona. There is no question that the water is polluted, but it is filtered before it is supplied to the inhabitants.

Dr. SOPER:

I think, Mr. President, that the only material point about the matter is, that the conditions at Hamburg are no criterion of what might occur here. The water there is not saline. Here we have a mixture to deal with. The sewage diffuses at Hamburg, where undoubtedly it would not be so diffused if the water were sea water. The sewage rises to the surface as excrement in Boston harbor and elsewhere. Of course, the cause is the difference in specific gravity and temperature.

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